December 1952

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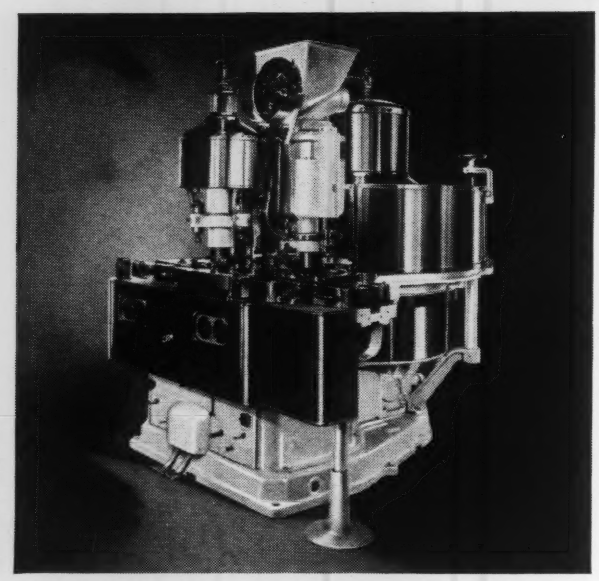

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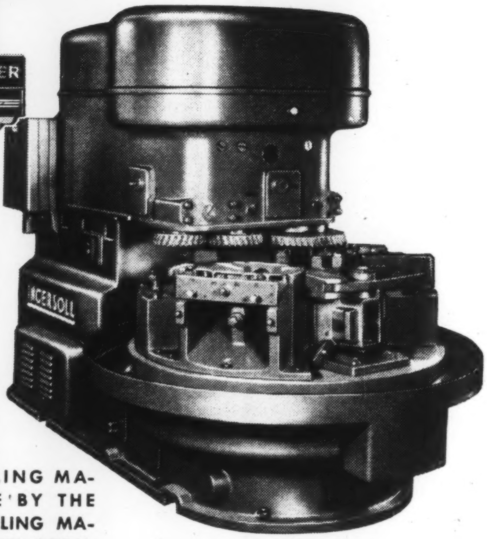

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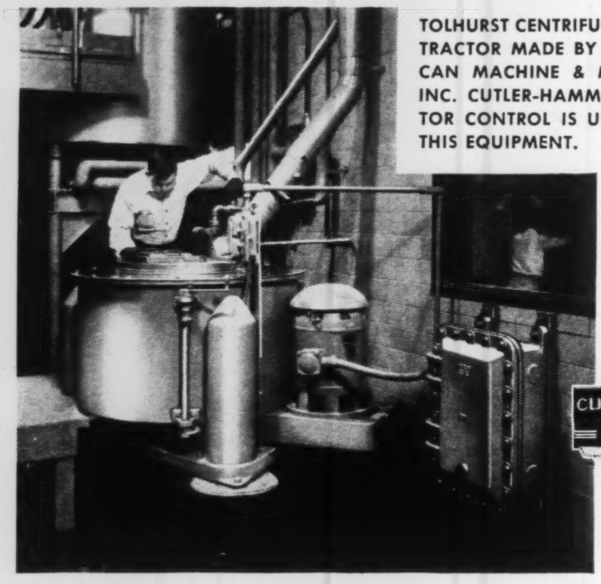

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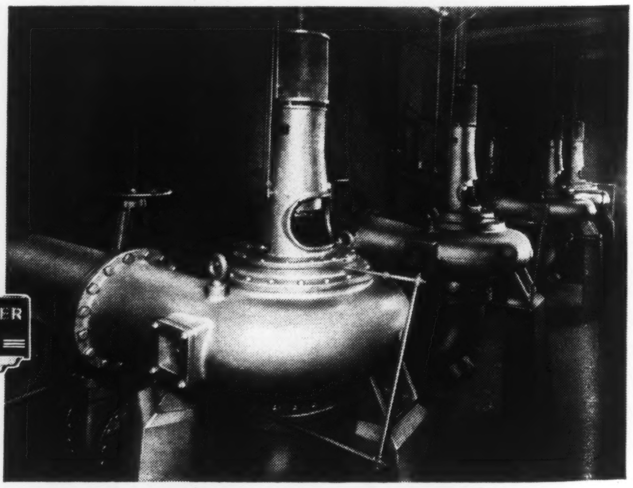

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MACHINE DESIGN

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Over the Board

"Blood Test" for Enamels

In the course of running down information for the series of articles on vitreous coatings starting on Page 165, we ran across a rather interesting "blood test" formerly used to measure adherence of porcelain enamels. Requiring skill, nerve and stamina, the test consisted of bending an enamel-coated specimen into a 90-degree angle and then running a finger along the bent edge. If the coating had fractured and was sharp enough to draw blood, the part was rejected. Certainly very simple, but we suspect that more inspectors failed the test than components being tested.

Some Machine!

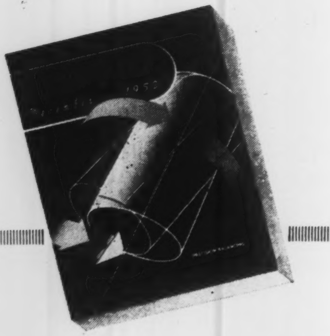
One of the most amazing bits of designing we've ever heard of is the human body. In a space of less than 9 cubic feet is packed a pump capable of continuous operation for 103,689 cycles per day; a control system consisting of 7 million units (brain cells); a bellows which operates 23,240 times during a 24-hour cycle; and a loudspeaker which emits about 4800 words in the same period. Add to that the low consumption of about 3½ pounds of fuel in the same time, and you have some idea of the exceptional efficiency of this complex device. Sometimes we can only thank the manufacturer fervently for having done such a competent job of engineering.

Deciphering a Color Code

After re-examining the cover of our October issue, we begin to appreciate the difficulty that stock clerks must have in keeping their code books up to date. As you probably remember, the cover showed a group of color codes and numerical designations for various steels. At the instigation of one of our eagle-eyed readers, we checked our designations and colors once again and found that two—X1112 and X1315—are obsolete. Color code for our editorial physiognomies is at present a brilliant blushing red.

This Month's Cover

As experienced TV-viewers, we weren't too dazzled by George Farnsworth's portrayal of the balancing of a rotating part on this month's cover. Seeing three overlapping views of the same object at the same time is old stuff, and we have reached the point where we can sit back comfortably, without leaping for the control knobs, and enjoy all three pictures. If the cover gets too bewildering, however, you may wish to turn to Sergei Guins' excellent article on precision balancing which appears on Page 121.



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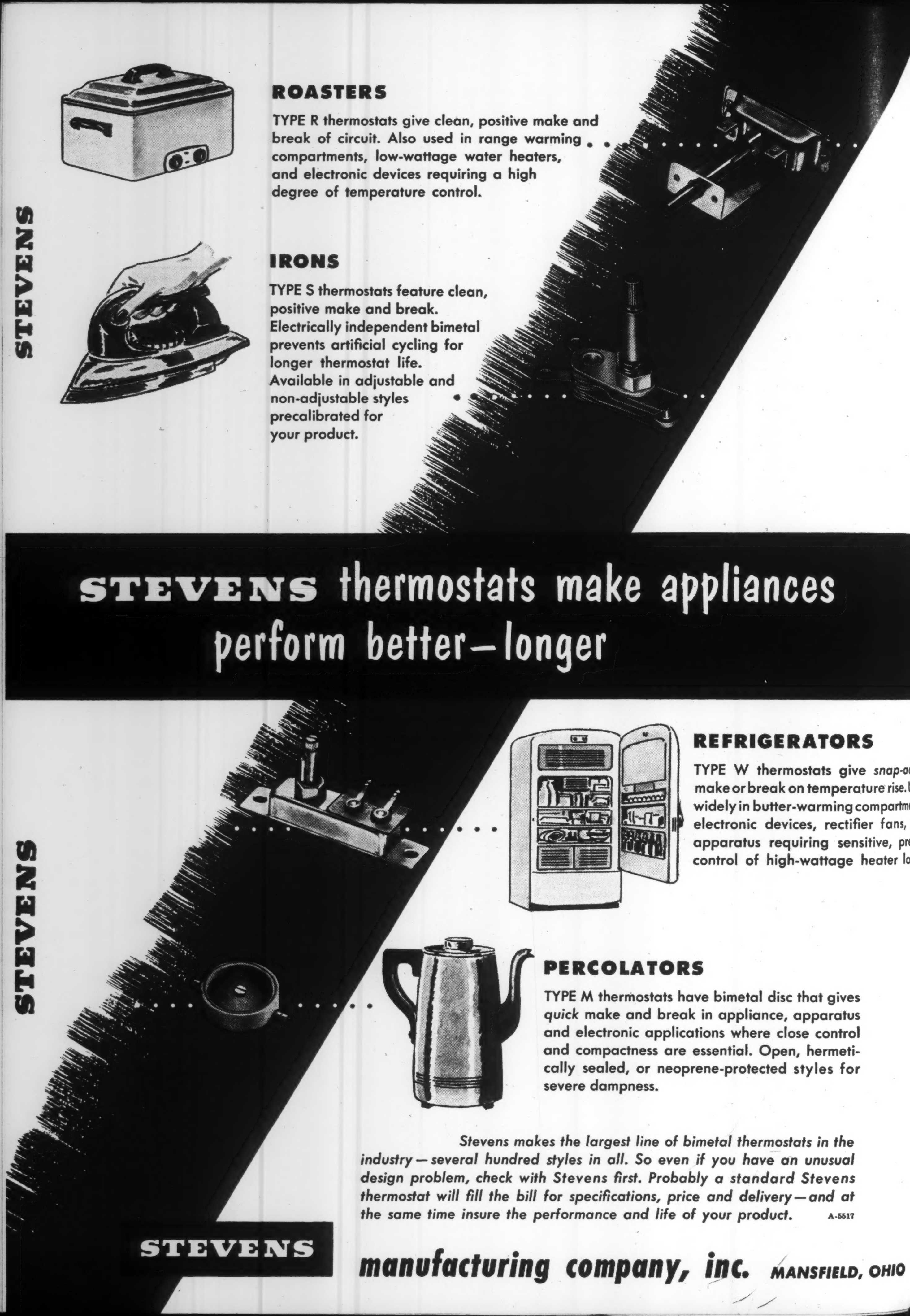

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IRONS

TYPE S thermostats feature clean, positive make and break. Electrically independent bimetal prevents artificial cycling for longer thermostat life. Available in adjustable and non-adjustable styles precalibrated for your product.

STEVENS thermostats make appliances perform better—longer

STEVENS

REFRIGERATORS

TYPE W thermostats give *snap-a*
make or break on temperature rise.
widely in butter-warming compartm
electronic devices, rectifier fans,
apparatus requiring sensitive, pr
control of high-wattage heater lo

PERCOLATORS

TYPE M thermostats have bimetal disc that gives *quick* make and break in appliance, apparatus and electronic applications where close control and compactness are essential. Open, hermetically sealed, or neoprene-protected styles for severe dampness.

Stevens makes the largest line of bimetal thermostats in the industry—several hundred styles in all. So even if you have an unusual design problem, check with Stevens first. Probably a standard Stevens thermostat will fill the bill for specifications, price and delivery—and at the same time insure the performance and life of your product. A-5517

STEVENS *manufacturing company, inc.* MANSFIELD, OHIO

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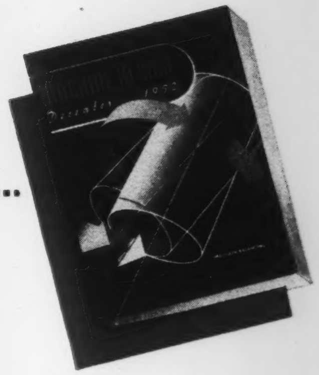


A Tip from the Medical Profession

WHOEVER heard of a doctor waiting to see a patient? Over the years the public mind has been conditioned to acceptance of the idea that the doctor's time is the most precious in the world. The impression is firmly backed up by the wide use of nurses, laboratory technicians and other aides for routine jobs so that the doctor's work is, supposedly, only performed on the highest professional plane.

Today, in proportion to the work to be done, engineers are in as much demand as doctors, if not more so. In spite of this, too little effort is being made to utilize their time to maximum effectiveness in creative engineering effort.

In a recent report, *How To Improve the Utilization of Engineering Manpower,* the National Society of Professional Engineers lists some of the tasks on which engineers often must spend their time, but which forward-looking companies have proved can be equally well done by subordinates. These include: drafting, incorporating changes on drawings, collecting and collating data, calculating and computing, expediting, record keeping, filing, requisitioning, checking orders for material, preparing charts and graphs, expanding standards books, handling details with shops, investigating customer complaints, operating experimental equipment, preparing portions of surveys and studies, transmitting information, and so on.

Instead of bewailing the so-called shortage of engineers, engineering executives might profitably take a leaf out of the doctors' book and so organize the work of the design department that technical aides do much of the spadework, legwork and paperwork now absorbing valuable engineering manhours. Matching the medical laboratories, too, there are consulting organizations which are set up to do many of the foregoing tasks, often better than the manufacturer's own people can.

Like the doctor, the engineer should be too valuable a man to spend much time on chores—or even on waiting to see his "clients."

Colin Carmichael

EDITOR

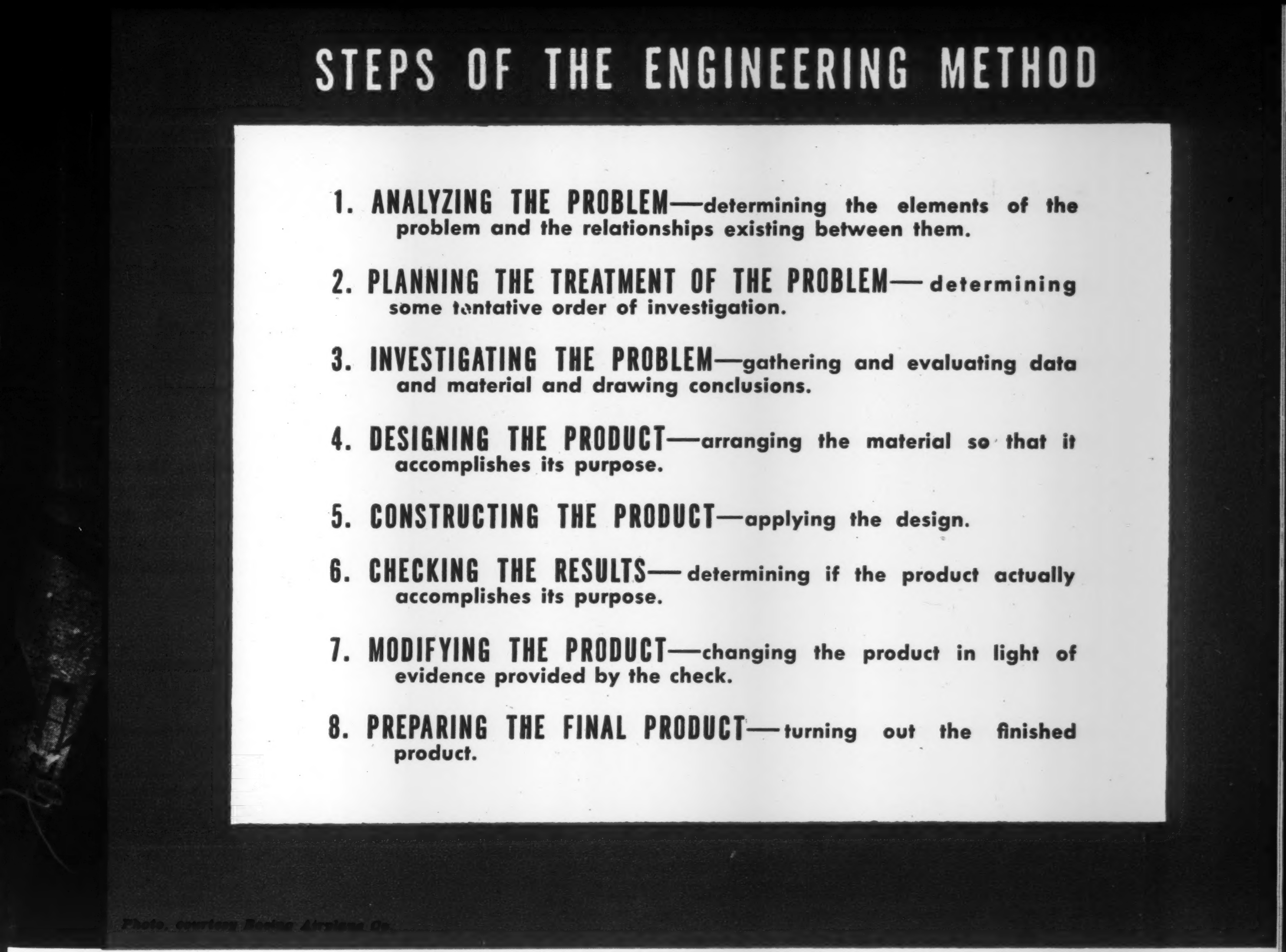
Applying the Engineering Method to

REPORT WRITING

THE secret of effective report writing is to be found in the application of the engineering method to the solution of writing problems. An analysis of technical reports indicates that, in general, writers face two main difficulties: (1) the problem of designing their reports to do a specific job in a particular technical situation and (2) the problem of knowing where to start and what steps to follow in the writing of a report. Unfortunately, most suggestions regarding reports so often deal with only the finished product, describing it in detail but ignoring completely the process by which it is evolved. Yet, this phase of writing is the one with which most writers have the greatest difficulty.

In writing as in design, quality products depend upon accurate and complete analysis, detailed and purposeful planning, and careful and select application. Every element of the problem must be taken into consideration and a knowledge of the available tools and devices brought to bear on the solution. Usually able to solve design problems within their own technical areas, engineers need only apply the same method to their writing problems in order to achieve more effective results.

The eight basic steps of the engineering method (above), are applicable to writing problems and, as in engineering, each is important. The particular items to be considered in solving writing problems, however, need further explanation, for they may represent unfamiliar material to some engineers.



STEPS OF THE ENGINEERING METHOD

1. **ANALYZING THE PROBLEM**—determining the elements of the problem and the relationships existing between them.
2. **PLANNING THE TREATMENT OF THE PROBLEM**—determining some tentative order of investigation.
3. **INVESTIGATING THE PROBLEM**—gathering and evaluating data and material and drawing conclusions.
4. **DESIGNING THE PRODUCT**—arranging the material so that it accomplishes its purpose.
5. **CONSTRUCTING THE PRODUCT**—applying the design.
6. **CHECKING THE RESULTS**—determining if the product actually accomplishes its purpose.
7. **MODIFYING THE PRODUCT**—changing the product in light of evidence provided by the check.
8. **PREPARING THE FINAL PRODUCT**—turning out the finished product.

Photo, courtesy Boeing Airplane Co.

By James W. Souther

University of Washington
Seattle, Wash.

Analyzing the problem

- **What is the purpose of the product?**
- **How will it be used?**
- **Who will use it?**

The point of attack in report writing as well as in engineering is the analysis of the problem—determining the purpose, the industrial role, and the audience of the report.

A report directed toward a stricter observance of recommended engineering practices in a particular section will differ from one which is merely a survey of adherence to present recommended practices. Both will differ from one which aims at improvement and extension of the recommended procedures themselves. The difference in the reports arises from their different purposes. The first stipulates clearly and concisely what is to be done in the future; little mention of old practices is needed. In the second, a statement of past procedures and of the adherence to them makes up the report. In the last, a statement of recommended modifications and additions to past rules is the essence of the report. Each differs as its purpose differs.

For example, if a report is to be used for reference, its engineering role requires that it be complete in all details since the material will probably be unfamiliar to the reader when the report is used—at least the immediate context from which the report sprang will have long disappeared. Moreover, in this kind of a report, the organization must provide easy access to all parts of the report, for its content, scope and data must be clearly identified if it is to be useful, if it is to fulfill its industrial role.

In addition to the purpose and industrial role of the report, the writer must determine, as best he can, who will use it and what the reader specifically desires. He must consider the education and experience of the reader, for these factors will determine the amount of detail and the level of technical language and usage which the writer can safely incorporate in his report. For example, a report describing a new home appliance to a mechanical engineer will obviously differ from one for the average consumer.

Examination of only a few engineering reports will reveal what happens when the writer fails to analyze the writing problem. Such reports no more satisfy their requirements than does a mechanical desi which has not grown out of a study of the desi problem.

Planning the treatment of the problem

- **What elements are of major importance?**
- **What aid is available?**
- **What tentative plan should be followed?**

If the report is to be successful, the writer mu determine what is of most importance to his read and to the purpose of his report. He should dete mine whether facts, results, conclusions or recon mendations are most vital to the industrial action l is striving to accomplish.

Check List for Effective Report Writing

I. Analyzing the writing problem

A. Who will read the report?
B. What is the purpose of the report?
C. What industrial action is desired?
D. What is the scope of the report?
E. What specifically has been asked for?
F. How much time is allotted for the completion of the report?
G. What special directives or orders must be considered?

II. Planning the treatment of the problem

A. What kind of information must be included: facts, information, results, conclusions, recommendations, or a combination of these?
B. What is known; what is unknown?
C. Which elements are of major importance, which of minor importance?
D. What previous studies or reports can be of aid?
E. Who can be of aid?
F. What tentative order of investigation should be followed?

III. Investigating the problem

A. Are the data accurate?
B. Are the data complete?
C. Are there enough data for the proposed paper?
D. Have all the important phases been covered?
E. Which are the most important facts and results?
F. Do the conclusions actually grow out of the data?
G. Should the emphasis be placed on the data, the method, the results, or the conclusions?
H. Does the nature of the report require that all phases be presented in great detail?

IV. Designing the report

A. What organization will make the material best fulfill its purpose?
B. What level of technical usage can be understood by the reader?
C. How can the material be organized so as to be most useful and to save the reader time?
D. What particular form will best support the use to be made of the report?
E. Is a statement of authorization, purpose and scope required?
F. Does the complexity of the report require a table of contents, an index, or an abstract?
G. What specific data, examples, details, and illustrations are required for clarity of meaning?
H. What facts must be interpreted?
I. What parts of the report must be emphasized?

V. Constructing the report

A. Follow the determined organization.
B. Do not waste time trying to get started; come back to the beginning later.
C. Write as rapidly as possible, leaving exact wording and mechanics to be checked over at a later date, in order to have life and continuity in the report.
D. Work in stages if the report is long and complex.
E. Include everything of importance; the report can be cut later.

VI. Checking the report

A. Organization
  1. Is the identity of the subject clear from the beginning?
  2. Is space wasted at the beginning of the report?
  3. Is the subject advanced by clear-cut stages?
  4. Is the relationship between one stage and the next clear?
  5. Does the conclusion leave the reader with the desired point of view?
B. Content
  1. Is the material complete enough to accomplish the purpose of the report?
  2. Are more examples, details, facts or illustrations needed?
  3. Do the facts require more interpretation?
  4. Are the major points emphasized enough?
C. Form
  1. Does the form make the parts easily accessible?
  2. Is the beginning and the end of each section indicated by the use of titles and proper spacing?
  3. Does the form of the report represent the co-ordination and subordination of the material?
  4. Are organizational devices needed: tables of contents, indexes, abstracts, etc.?
D. Style
  1. Does the style facilitate rapid reading?
  2. Is the exact meaning conveyed?
  3. Is the report clear for later reference?
  4. Is there any deadwood to be removed?
  5. Are the sentences direct and effective?
  6. Are the mechanics correct?

VII. Modifying the report

A. Make the necessary changes, additions, or deletions in the content of the report.
B. Make the necessary alterations in the organization of the report.
C. Make the necessary mechanical and stylistic alterations.
D. Make necessary changes in form.

VIII. Preparing the final report

A. Use standard materials.
B. Be neat and accurate.
C. Make only small changes on the finished manuscript.

Competent engineers frequently fail to determine what is essential to the report which they must write. They fail to distinguish between the *important* and the *related.* Then, playing safe, they cover all phases of the problem. Although the most important material is included in the report, it is so hidden in related but less important material that the report becomes useless. It becomes ineffective because it has lost direction.

Once the writer has distinguished between the elements of major importance and those of lesser importance, he is in a position to consider in proper perspective the task facing him. He can then form a tentative plan of attack based on a thorough analysis of the problem he faces. He knows what he is attempting to do in his report; he knows what is of major importance to his task; he knows what he must do in order to complete the report. With this knowledge he can plan his program for solving the problem and writing the report.

Investigating the problem

- **Are the data accurate and complete?**
- **What are the results?**
- **What conclusions can be drawn?**

Investigation of the problem is the stage of report writing where the engineer has least difficulty; here he is quite at home. He is particularly adept at gathering material, and accuracy and completeness of data are generally the rule. Yet, the results achieved, or the conclusions drawn, are often of much greater importance to the industrial function of the report. For example, a report which is to determine whether or not money is to be invested in a new product line must emphasize results and conclusions, for it is on them that the financial decisions will be based. If a report is a weekly progress report, however, the data are of prime importance and conclusions are not usually included.

Since the engineer is trained in the techniques of gathering his technical material, little need be said of them. It is important, however, that he be warned of the unnecessary work that often results from failing to realize what is basic to the study. Often, much time and labor are spent gathering information which would obviously prove not germane to the project had proper consideration been given it.

Designing the product

- **What design will make the data best fulfill its purpose?**
- **What design will make the data most useful?**
- **What design will emphasize the important parts?**

After the material is gathered and evaluated, the writer faces the all-important task of organizing his material, of *designing* the report he is to write. From the many possible ways of organizing his material, the writer must choose the particular one which he feels is best. Such a choice, to be effective, must be based on a realistic analysis of the problem. Success or failure depends on the ability of the report to satisfy its industrial function. The material must be organized so that it accomplishes its purpose of clearly communicating to others the exact information intended, whether it be a recommendation to a board of control, a financial statement of the quarter, a statement of project progress, a result of a laboratory test, or a procedure for soldering electrical connections. Each statement must look both backward and forward; each must be a bridge over which the reader can easily move in his efforts to understand the report.

In addition to being clear and understandable, the material must be organized so as to be most useful to the reader, and the writer must constantly keep the needs of the reader in mind if his report is to be effective. The growing demand for abstracts and summaries in industrial reports stems from their usefulness to the people who use the reports. The effective report writer will place the material which is of greatest interest to the reader at the beginning of the report, for very often the order in which the writer gathered his material, or the order in which the test was conducted, is not the most satisfactory arrangement for the report which covers them. The results and conclusions, in most cases, are far too important to be placed at the end of the report, and the efficient report writer places them in a position of emphasis, near the beginning.

Good report form is more than attractive; it is functional as well. Effectively designed reports save the reader time by having all parts clearly identified through proper use of titles and subtitles. Sections of equal importance are given identical physical arrangement, and relationships of subordinate sections are made obvious at first glance by the manner in which they are placed on the page. Good form is an extension of the basic organization of the material within the report. The format is a pleasing graphic expression of the structural development of the material contained.

Constructing the product

- **Has the determined organization been followed?**

Once the report has been designed, the writer should write as rapidly as possible in order to give life and sparkle to his phrasing, as well as to save the continuity of ideas which is often destroyed by constant rework and polishing. In the first draft, he should pay little attention to the mechanics of writing, for these can be corrected before rewriting. Moreover, when he is in doubt about including any information, he should remember that it is much easier to cut than to expand. If the report is long and complex, the writer will often find his work easier if he writes each stage of it separately, finishing one part before moving to the next.

Although the report should follow the determined organization, the writer, however, should not make himself a slave to his plan. Any new ideas which occur during the writing should be added. The writer will also find it is much easier to rewrite his own material effectively if he will wait a day or two before reworking it.

Such items as abstracts and summaries should not be written until the report is finished, for reading and outlining the report will provide the writer with the essential information for his abstract or summary.

Checking the product

- **Is the product complete?**
- **Are the proper elements given importance?**
- **Does the product accomplish its purpose?**

Upon completion of the first draft, preferably after some time has elapsed, the writer should thoroughly check his report for organization, content, form and style. Often he will find it quite helpful to have someone else check the report to see whether it is clear and achieves its intended purpose. Then, trying to place himself in the position of the reader, the writer should determine whether or not the subject is clear at the beginning, for there most space is wasted. He should make certain that the direction of movement within the report is logical and clear—that the relationship between facts and their interpretation, between data and conclusions, is made obvious both by the arrangement of material in the sections and by the arrangements of the sections in the report. The data must be interpreted for the reader, for contrary to a popular notion, facts do not speak for themselves. The efficient report writer interprets them so that his reader cannot misunderstand. Most important of all, however, he should determine whether or not the report will leave the reader with the desired point of view—whether or not it does what it was meant to do.

The report should be checked for clear identification and easy accessibility of all parts. The form, supplementing and supporting the organization of the contents of the report, should make all titles clear—headings, capitalization, and spacing should be consistent. Identical format should apply to sections of equivalent status; headings or position on the page should differentiate major and minor sections. In addition, consideration should be given to organizational devices such as a table of contents, an index and an abstract.

In matters of style, the writer should carefully check his report to see if the exact meaning is conveyed and whether or not "deadwood" can be removed. He should make every effort to be as direct and as concise as full understanding will allow. Finally, he should check his report for mechanical errors in spelling, punctuation and grammatical construction.

One word of warning should be offered at this point: the writer should make every effort to take a detached attitude toward his report. He should not become so *ego-involved* that he resents any criticism of his report. The detached viewpoint is necessary to both comfortable working relationships with others and effective report writing.

Modifying the product

- **Have the required changes been made?**

After the report has been thoroughly checked, it should then be modified and corrected. The weaknesses indicated by the check should be overcome and the errors removed. Both the check and the modification should be made with the reader and the purpose of the report clearly in mind, for they govern both.

Preparing the final product

- **Have standard materials been used?**
- **Is the product accurate?**
- **Have only small alterations been made on the finished product?**

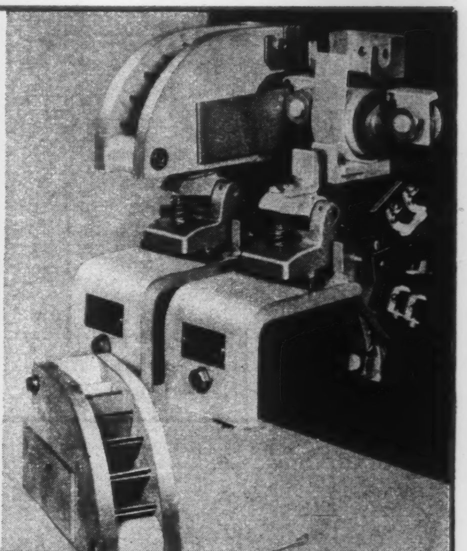
In preparing the final copy of his report, the writer should make certain that standard materials are used and that the copy is neat and accurate. Once it is finished, only minor changes should be made, for both its appearance and its effectiveness influence the writer's reputation.

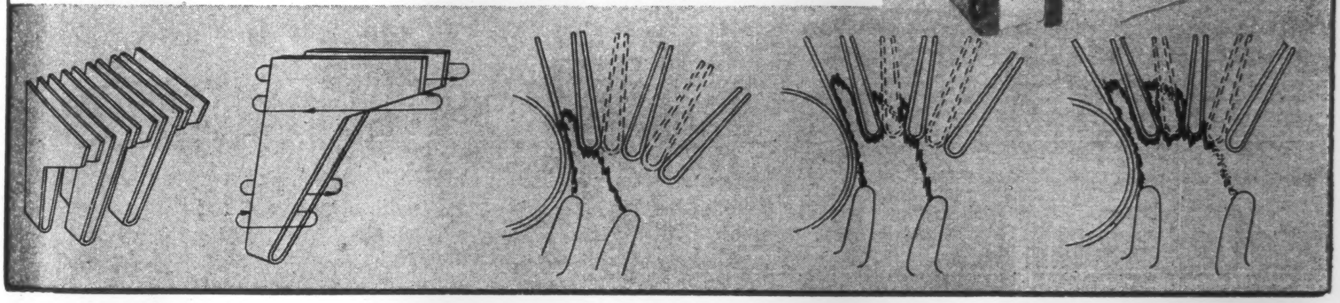
Application of the engineering method to the solution of writing problems is certain to produce more effective reports, for it is a realistic approach to the problem of designing reports to meet their particular roles. Reports, like all engineering products, must be designed to satisfy a particular function which presents its own specific set of requirements. Since success in report writing depends on the ability to communicate, the report's purpose, use and readers must always be its main guiding principles. Application of the eight basic steps of the engineering method, with attention to the details included in the accompanying check list, should produce reports that will better fulfill their intended functions.

"The average machine designer is a most peculiar fellow when it comes to the most important part of his machine, the motive power and its control. He likes to put the electrical equipment (if he even gives it a thought) in the most hidden places he can think of, or he ignores it completely until after the machine design is completed. When the latter is true, he assumes that all that is necessary is to throw it at the machine, and let it stick where it may, as long as it does not interfere with the symmetry of his design."
—C. D. COFFIN, *chief electrical engineer, Euclid Tool Sales Co.*

SCANNING the Field for IDEAS

FAST ARC EXTINCTION and current interruption result from a new principle embodied in the Allis-Chalmers heavy-duty dc contactor. Staggered U-shape fingers in the arc chute stretch, cut and cool the arc rapidly. A blowout coil and arc runner force the arc into the arc chute and as it strikes the loop end of each segment, a magnetic field transverse to the current is established and forces the arc up toward the center of the chute as indicated in the accompanying sketches. Both thermal convection and magnetic action stretch and cool the arc, resistance of the arc path increasing as the number of gaps between elements increases. Oscillogram records show an arc time of about one cycle duration.

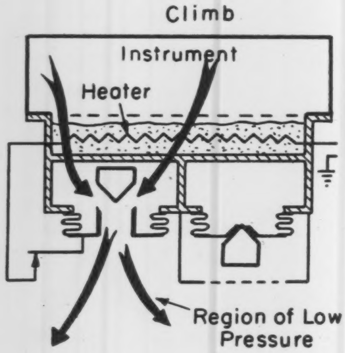


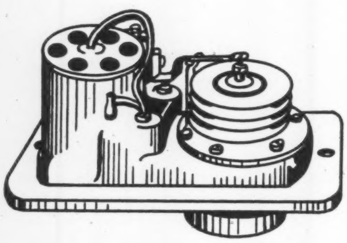


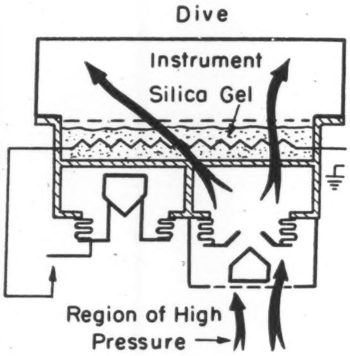
ELECTRIC HEATING via printed circuit techniques offers advantages where uniform heat, low surface temperature of the heating element, low infra-red radiation and high energy exchange are desirable. Thermflex radiant heating elements can be used to heat practically any surface or contour uniformly, within the limits of the base and insulating materials, up to a maximum of 400 F. Developed by Radio Ceramics Corp., these coatings can be bonded to phenolics, glasses, ceramics, asbestos papers, glass cloth, insulated metals, etc., and consist of resistance compounds with carefully controlled characteristics. Present applications are found in aircraft instruments, cameras, meters, de-icers, and other equipment where application of heat is otherwise difficult. A typical heater element bonded to a cylindrical surface is shown.

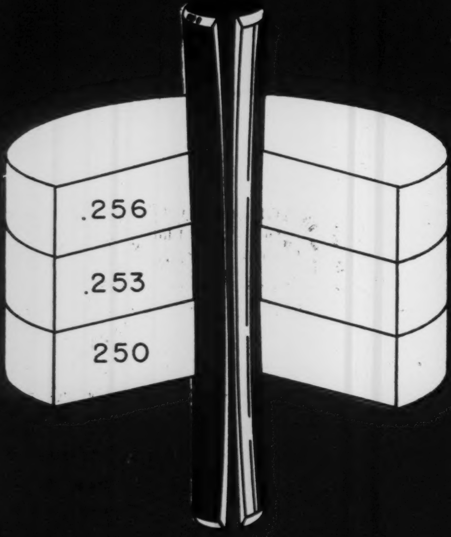
IDEAS

MINIATURE AIR CONDITIONING SYSTEM developed by Daco Machine & Tool Co., protects aircraft gunsights against fogging, freezing and dirt infiltration. Operation of the unit is indicated in the accompanying sketches showing air movement under climb and dive conditions. As outside air pressure diminishes, the left valve bellows opens and actuates a switch to turn on a reactivator heater located in the silica-gel desiccator bed. Air in the instrument scavenges the gel bed of moisture until pressure equalization is reached when bellows closes and shuts off the heater. When outside air pressure increases, the right valve bellows opens and air passing in is dried and filtered as pressure equalizes.

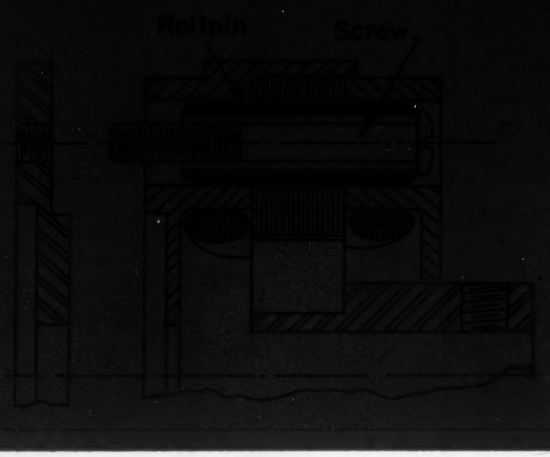








DUAL-PURPOSE FASTENING of three main stator parts in the Allard Instrument Corp. synchronous brake is achieved with Esna Rollpins. The stator is assembled with the laminations held between aluminum cover plates containing the windings. Split, hollow Rollpins pressed into production drilled and blanked holes hold the assembly and simultaneously provide holes for long mounting screws. Pin design permits positive retention with normal production spread of tolerances, as indicated, without seaming, riveting or peening.



Precision Balancing

. . . of rotating machine parts

As speeds of machines increase simultaneously with decrease in weight, dynamic balancing assumes added significance and importance in design

By Sergei B. Guins and John Burmist

Research Engineer
Chesapeake and Ohio Railway Co.
Cleveland, Ohio

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INCREASED speeds with decreased weight and cost rank high among today's design goals. However, as the engineer strives to reduce the weight of machines along with simultaneous increase in produced or transmitted power, the effects of unbalance are magnified tremendously. As a consequence, it is increasingly important that this problem is thoroughly understood and the method of balancing and its effectiveness is brought to a high point of accuracy.

Early rotating elements of machines were mounted in heavy, rigid supports and their speed of rotation was slow. Forces produced by unbalance, being proportional to the square of the velocity, were of low magnitude and were absorbed in the frame without emphasizing their existence. To be noticed, vibration produced by unbalance must demonstrate itself either by noise or movement of a machine frame. As long as normal speeds of rotating elements were low, their frequencies were below the objectionable or even troublesome level and, therefore, the only sign of vibration was amplitude of motion.

Effect of unbalance on a heavy mass can be derived easily from the basic principles expressed in the following:

$$Fc = \frac{W_1 r}{g} w^2 \qquad (1)$$

where F_c = centrifugal force, pounds; W_1 = unbalanced mass, pounds; r = radius, inches; g = gravity, 386 in./sec²; and w = cycles per second.

$$S = \frac{-a}{W^2} \sin wt \qquad (2)$$

where S = displacement due to harmonic motion, inches; a = acceleration, in./sec²; and t = time, seconds.

$$F = ma = \frac{Wa}{g} \qquad (3)$$

where F = inertia force, pounds; and W = total vibrating mass, pounds. Substituting Equation 3 in Equation 1 gives

$$\frac{Wa}{g} = \frac{W_1 r}{g} w^2$$

Also, substituting U for $W_1 r$, which is the unbalance in pound-inches, yields

$$a = \frac{U}{W} w^2 \qquad (4)$$

Finally, combining Equation 4 with Equation 2,

$$\frac{S}{W} = U \sin wt$$

or for maximum amplitude, when $\sin wt = 1$,

$$U = SW \qquad (5)$$

Equation 5 provides the desired relationship between the weight of the machine, its amplitude and the unbalance. This indicates that, for heavy machinery, unbalance has to be large in order to produce objectionable displacement.

A good example of this condition is in the suspension of a railroad car. In an effort to improve the ride of passenger cars, effect of unbalance of railroad wheels was investigated. A car set of wheel and axle assemblies was balanced and installed on a railroad coach. Accelerometers were mounted on the frame of the truck and in the car body. Inasmuch as only longitudinal forces produced by static unbalance of the wheels could be transmitted to the car body, the instruments were so mounted that they recorded these forces.

Records were taken at various speeds, first with balanced wheels, and then with unbalanced wheels to which various known weights had been attached. It should be noted at this point that the frame with two wheel and axle assemblies weighs about 17,000 pounds and the whole car weighs 120,000 pounds. The tests indicated that for normal speeds of the train, which are under 80 mph, the unbalance usually encountered with machined railroad wheels can be tolerated insofar as comfort of passengers is concerned. However, at higher speed, say up to 120 mph, this unbalance must be reduced to below 2.5 lb-ft to maintain the same order of ride comfort. The same condition is true for many other types of machinery when speeds are increased. Also, conversely, with reduction in weight possible through use of high-strength alloy steels, flexibility of the rotating members is increased, rigidity and weight of the supporting structure is reduced, and the problem of unbalance becomes more critical.

Causes of Unbalance: If the rotating element is not symmetrical, it is easy to see how unbalance

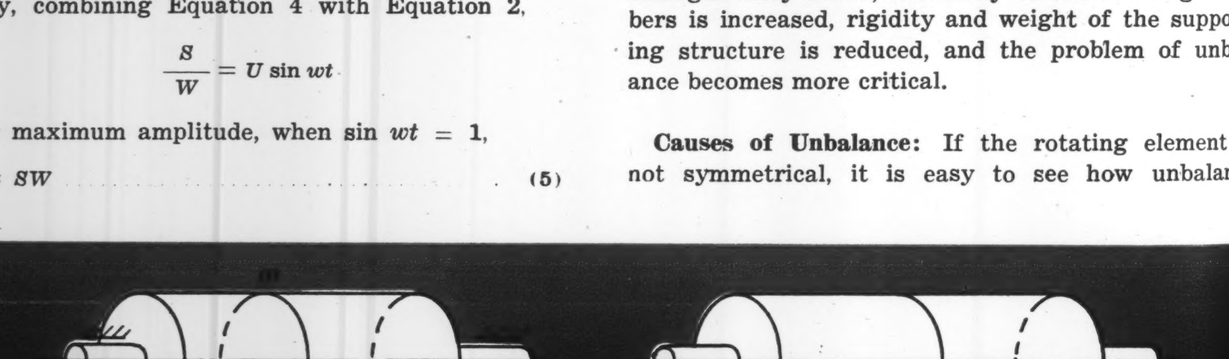


Fig. 1—Simple cylindrical roll *a*, and case of static unbalance *b* where centers of gravity of both sections are on the same side and in the same plane

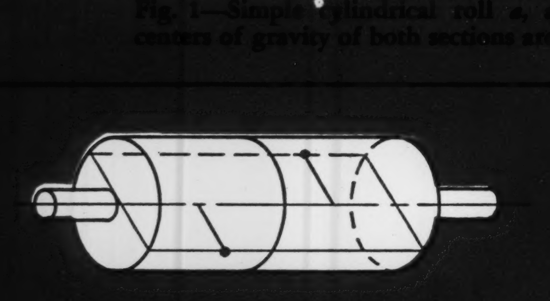


Fig. 2 — Case of dynamic unbalance showing centers of gravity on opposite sides but in same plane

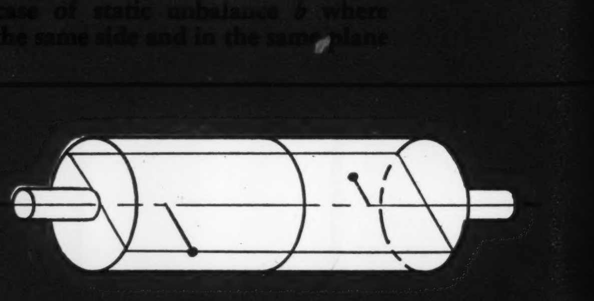


Fig. 3 — Combined static-dynamic unbalance of the roll in *Fig. 1* with centers of gravity in different axial sections

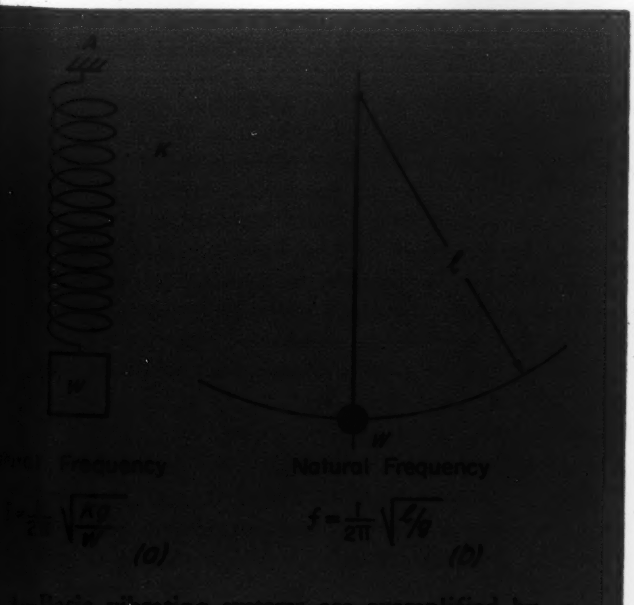
would be produced, as to have a balanced element, the axis of rotation must coincide with one of the principal axes of inertia of the body. On the other hand, in a seemingly symmetrical body, these two axes might not coincide due to the nonhomogeneity of the material or slight errors in dimensions.

Types of Unbalance: In order to understand and define conditions of unbalance, consider a simple roll as shown in *Fig. 1a*. If this roll is divided in two parts by cross section *mn*, three general cases of unbalance which occur may be explained.

STATIC: The centers of gravity of both parts can be in the same axial plane and on the same side of the axis rotation, *Fig. 1b*. This static unbalance can be detected and/or measured easily by statical test. In the simple case of an automobile wheel and tire, we know that if it has static unbalance, the heavy part of the assembly will always gravitate to the bottom when the wheel is jacked off the ground and given a spin.

DYNAMIC: If centers of gravity are in the same axial plane but on the opposite side of the axis of rotation, *Fig. 2*, and at such radial distances that the center of gravity of the whole body will be exactly on the axis of rotation, dynamic unbalance produced is not easily determined by any simple method. It will manifest itself, only when the body is rotated in such a case, by vibration of the whole machine foundation.

COMBINED STATIC-DYNAMIC: The most general case encountered is one that is composed of these two preceding cases and is schematically illustrated in *Fig. 3*, where the two centers of gravity may lie in different axial sections. This system, when rotated, will produce two forces caused by the centrifugal forces of the two masses. These compound forces, however, can always be reduced to a system consisting of a couple acting in an axial section and a radial force which together produce simultaneous static and dynamic unbalance.


A
K
W
al Frequency
$f = \frac{1}{2\pi}\sqrt{\frac{Kg}{W}}$
(a)
l
W
Natural Frequency
$f = \frac{1}{2\pi}\sqrt{l/g}$
(b)

—Basic vibrating systems are exemplified by, *a*, mass and spring and, *b*, simple pendulum

Vibration Systems: To better understand the effects produced by unbalance forces and the principle of the machines used for balancing, it is helpful to study the problem from the standpoint of vibrating systems. These are: (1) Free vibrating systems and, (2) forced vibrating systems.

FREE VIBRATING SYSTEMS: Practically any structure can be reduced to a simple mass and spring or a pendulum system, *Fig. 4*, where *W* represents the weight of the part and *K* or *l* its flexibility. If weight *W* is displaced and then freed, it will perform regular oscillations that can be represented by sine and cosine functions, which will be characterized by waves of equal length and amplitude.

This, of course, is for ideal conditions only. In practice, the energy will be gradually dissipated and the amplitude of the oscillation will gradually be reduced to zero, but the wave length will remain constant. This wave length is the natural period of vibration and the number of times it recurs per unit of time, the natural frequency of vibration. From this, then, can be drawn the conclusion that every machine element has a natural frequency.

FORCED VIBRATION SYSTEMS: Assume that in a simple system, such as in *Fig. 4a*, point *A* starts to move up and down, at first slowly and then with increasing speed, to produce the phenomena known as forced vibration. At first weight *W* will move in unison with point *A*, but as speed increases, it moves more and more out of phase with point *A* and, as it does so, its amplitude increases gradually. At some speed a resonance condition is reached—weight *W* will start moving down when point *A* moves up, or vice versa—and if maintained for any length of time, the amplitude of the weight will tend to increase indefinitely and break the spring.

However, if the speed of point *A* continues to increase, the amplitude of motion of weight *W* will gradually decrease again and beyond a certain limit, the weight will stop moving. Described mathematically by a differential equation this phenomena produces the curve shown in *Fig. 5* when the amplitude ratio is plotted against the ratio of forcing frequency (speed of motion of point *A*) to natural frequency of the spring and mass system. From *Fig. 5* it is easy to see that the condition of resonance is produced when forcing frequency is equal to natural frequency. In *Fig. 6* results are given for a similar system, but including the effect of varying degrees of damping or external energy absorption on the amplitude of weight *W*. Identical conditions can be demonstrated if the pivot point of the pendulum is moved back and forth.

Effect of Unbalance on the Vibrating System: Because any machine consisting of moving parts and supporting elements is in essence a case of forced vibration, the phenomena encountered can be readily understood. For example, in the instance of an automobile in which the crankshaft is not properly balanced, operation at a certain speed will feel rough.

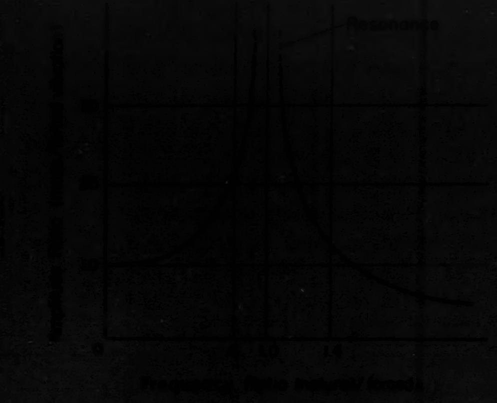


Fig. 5—Effect of forced vibration with amplitude ratio plotted vs. frequency ratio

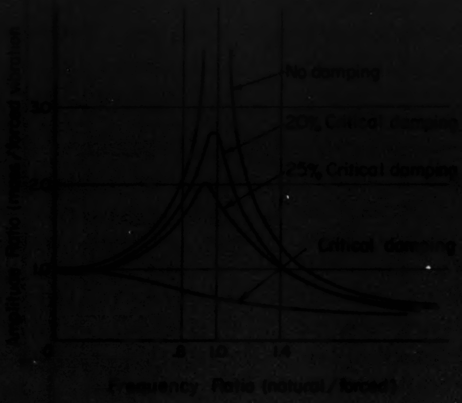


Fig. 6—Plot showing effect of various degrees of damping on amplitude

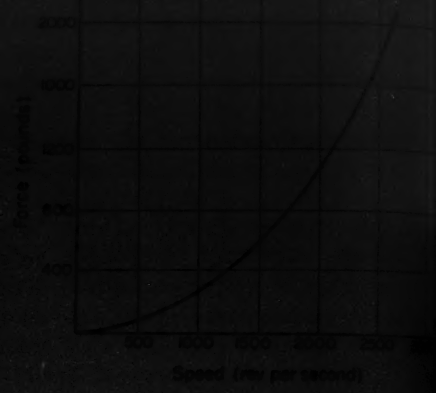


Fig. 7—Chart showing forc produced by one pound-fo of unbalance at various speed

but at higher speed, it becomes smooth again. This is also true for unbalanced wheels—they make the car bounce at some speeds, but at higher speeds, the ride becomes smooth again. Both these conditions are brought about by resonance of the engine mounts and springing of the car. Generally, the tendency is to try to avoid these speeds and eliminate the problem of unbalance. But, it is obvious that this is a dangerous fallacy as ride comfort is only one way in which unbalance manifests itself and actually, is probably the least critical consideration. The important factor is that it signifies the presence of impending danger. Most serious in this respect is the overloading of bearings and the imposing of additional stresses in the members that in many instances may already be highly stressed to reduce weight. As a consequence, the degree of balancing of machine components needed to correct the problem assumes key importance.

Principles of Balancing Machines: With the requirement of balancing established, the question arises, "How accurately should the rotating parts be balanced?" No specific answer can be given to cover all cases. The final specification depends on the particular application and the economics involved.

From Equation 1 or *Fig.* 7 it can be seen that the force produced by unbalance is directly proportional to the square of the rpm. This provides the first criterion—the higher the rpm, the closer should be the balance. Next, the design of the part itself must be considered. For example, if the design of a shaft and gear is for high performance, as is often the case in aircraft, the high-precision gear would not perform satisfactorily under any significant deformation. With design calculations based on actual gear loads and torques involved in the machine, assuming a minimum margin of safety, it becomes clear that any additional force might decide the success or failure of the machine.

If design is viewed from this standpoint, it is not difficult to estimate the maximum additional loads that can be carried without impairing the performance of the machine, and permissible unbalance can then be specified. The usual error in specifying permissible unbalance is to write it merely in the form of weight unbalance which is incomplete. It is necessary also to specify the distance from the centerline, so that the proper way to accurately specify is: "allowable unbalance of ...... inch-ounces" or "allowable unbalance of ...... ounces at ...... radius from centerline".

Next decision that must be made is whether the parts constituting the assembly should be balanced individually or as an assembly.* The recommendation here would be to balance complete assemblies when at all possible and also with the part resting on the bearings in which the assembly will be supported.

Most balancing machines utilize the phenomena of forced vibration in their construction either by taking advantage of the resonance condition at which amplitudes are highest and therefore greatest accuracy obtainable, or by the fact that at higher speed, the force produced by unbalance increases as the square of velocity and therefore can be more easily detected. The most common type of balancing machine is one in which correction weight and location are determined in two fixed planes of the machine and from there transferred to the planes in which correction is actually required. In cases when only static unbalance exists, this method is perfectly satisfactory as the correction can be carried from plane to plane without change in magnitude, provided it is made at the same distance from the axis of rotation.

This is not true of dynamic unbalance where the correction weight must be changed with the distance between planes in which the correction is made. If there is dynamic unbalance only, this also can be rather easily done. The problem starts when both types of unbalance are present but, when detected, appear as one weight in each plane. For this case, unless the proportion between two unbalances is known, an error can easily be made when correction is effected in a plane different from the one in which it is detected in the machine. The major difference in most balancing machines is the way in which the amount of correction and its location is found without stopping the machine for trials.

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*W. I. Senger—"Specifying Dynamic Balance," MACHINE DESIGN, December 1944 to February 1945.

One machine is unique in the fact that it utilizes the resonance principle in its construction and is so built as to detect static and dynamic unbalance separately. In *Fig.* 8 is a schematic diagram of this machine and in *Fig.* 9 is shown the actual machine with a crankshaft in position for balancing.

As shown in the schematic, *Fig.* 8, the table is a pendulum mounted on a fulcrum, consisting of a

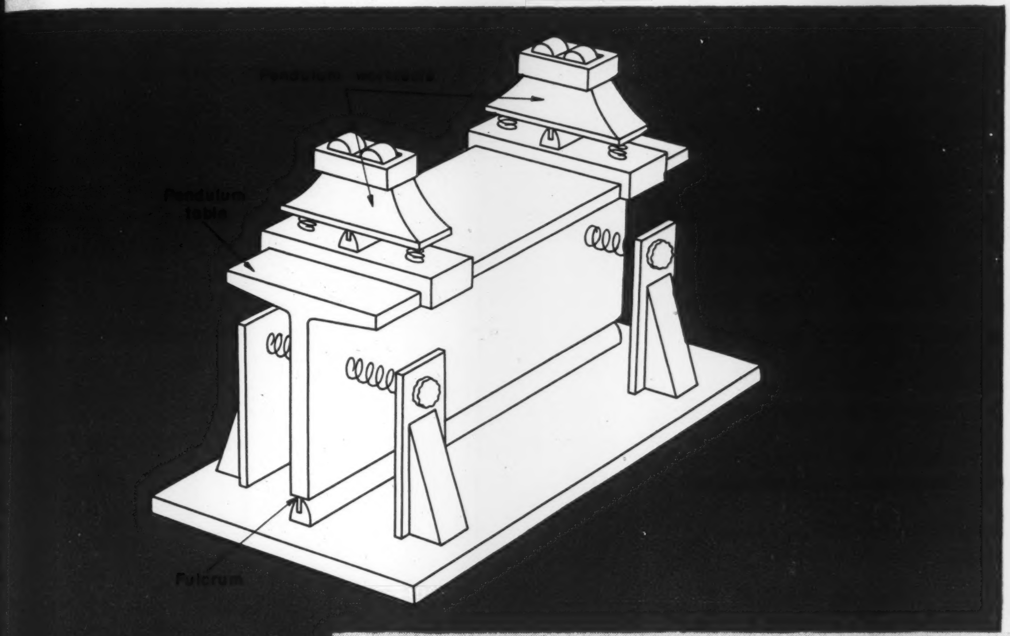

Fig. 8 — Above — Schematic diagram of Akimoff static-dynamic balancing machine

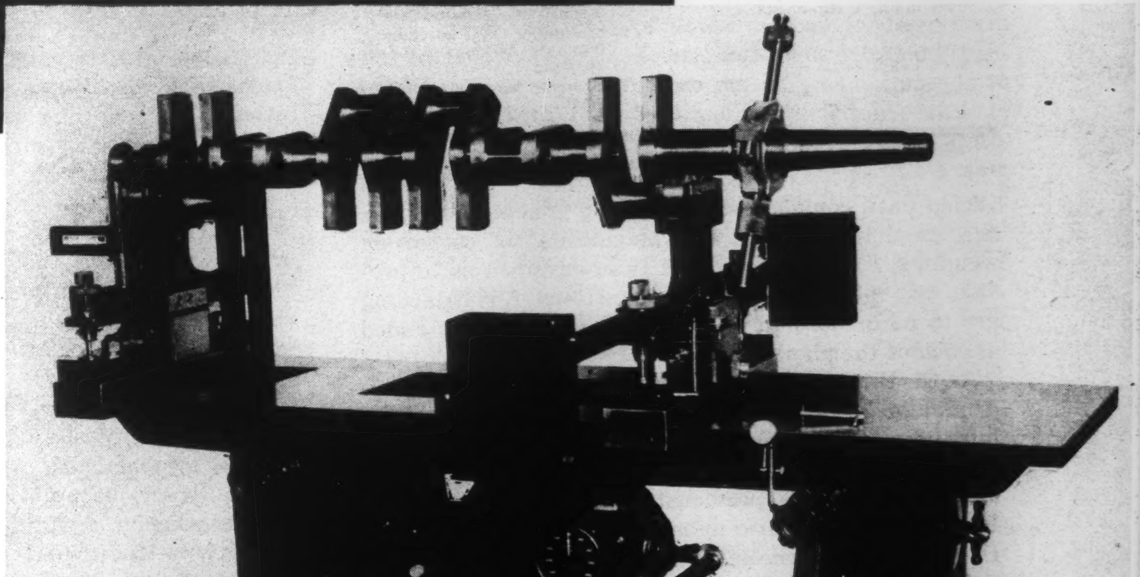

Fig. 9—Below—Akimoff balancing machine with crankshaft in position for balancing

spring-steel strip, and restrained by springs. On the table are mounted two pendulum workrests with rollers, each having a spring-steel fulcrum and adjustable spring side mounts. Both pendulums have adjustable stops so that they can be rendered stationary relative to the part on which they are mounted. A motor mounted on the table near the base fulcrum rotates the workpiece through a belt drive. Frequency of the table pendulum is made low compared to the frequency of the drive and the drive parts are carefully balanced, so as to eliminate adverse effect on the accuracy of the machine.

Procedure for balancing is as follows: The pendulum workrests are blocked and only the table pendulum is allowed to vibrate. Thus, the machine becomes sensitive to static unbalance only; the speed of the drive is adjusted to give maximum amplitude for the vibrating system and this speed is used throughout the remainder of the process. At this point, additional weight (usually clay) is attached to the work at various angular locations and a plot of amplitude (measured by a dial indicator) is made against location of the added weight. The point at which the amplitude is smallest gives the angular position for correction weight. Amount of correction weight is then varied until complete static balance is achieved. Thus, the angular location and magnitude of correction weight is found. If the part is so designed as to provide two planes in which corrections for balancing are to be made, half of the static correction is added at each of the planes.

With this initial procedure completed, the table pendulum is blocked and one of the workrest pendulums is released and adjusted both by location of the springs and added weights, *Fig.* 9, to give maximum amplitude for the previously established frequency. Inasmuch as all static unbalance has been eliminated, the pendulum workrest is excited only by dynamic unbalance present in the work. The same process as described for static balancing is now repeated, but the result gives the angular location and the unbalance couple producing dynamic unbalance. The couple thus determined will be equal to the distance between the stationary workrest pendulum and the plane in which correction weight is attached times the amount of the correction weight. If this couple is divided by the distance between the two planes in which the corrections are to be made, the amount to be added in each plane is determined. These weights must be 180 degrees out of phase with each other and the one nearest to the free workrest fulcrum is to be in the same angular location as the test weight.

Each plane then has two correction weights, one for static and another for dynamic unbalance. These two weights can be replaced by a resultant weight determined by a parallelogram of forces drawn from the axis of rotation through the two correction weight positions with vector magnitudes equal to the correction weights.

After final correction is made, the work is rotated at various speeds and if previous steps have been made carefully, there will be no vibration produced by the work in either pendulum. If, on the other hand, vibration is detected, the whole process must be repeated.

For most experimental work or when only a few pieces are involved, the foregoing method is highly satisfactory, but for production work devices can be used to indicate amount and location of correction weight automatically. Advantages of this type of balancing are quite obvious in view of the foregoing theory. All balancing is done at low speeds as the pendulums are adjusted for low frequencies; a high degree of accuracy is achieved because all the work is done at resonance with a minimum amount of damping.

Table 1—Methods of Designing for Unbalance Correction

Addition of Weight	Removal of Weight
1. Mechanical snap-on weights, drive-in plugs, slip-on strips, washers, etc.	1. Drilling of holes in preplanned non-stressed areas.
2. Solder, sweated-on weights, filled holes, etc.	2. Machining off of bosses, lugs, etc. designed-in for the purpose.
	3. Grinding where correction is small.

Design for Balance: From the foregoing it can be seen that the underlying principles of balancing are relatively simple as are also the processes leading to determination of the unbalance forces and their locations. The most difficult problem lies in the application of correction for unbalance. This depends entirely on the design of the part being balanced and therefore on the foresight of the designer. It is highly desirable that the designer check all precision rotating parts requiring balancing for places where correction can be made without affecting the strength or function of the machine.

Correction for unbalance can be made in two ways only: (1) By adding correction weights, or (2) by removing some of the material from the part. In the first case, some means of fastening must be devised and in the second case, places must be provided to remove weight. TABLE 1 shows some of the various methods applicable. In either case, if this problem were not considered during the original design, both the quality of the part and the cost and effectiveness of balancing would be affected. This is an especially serious problem in highly stressed parts.

In conclusion, a word of warning must be added. A perfectly balanced part may produce vibration due to other factors such as the critical speed of the part or, in some cases, aerodynamic or hydrostatic forces which haven't been considered. For instance, a marine propeller mounted too close to the hull would vibrate due to hydrostatic forces. Effect of speed on the shape of part must be considered also. For example, a tire which is flexible enough to change its shape due to centrifugal forces will have considerable effect on balance. When such parts are balanced, checks must also be made at operating speeds.

The designer should specify the minimum accuracy or the maximum amount of unbalance permissible, as it greatly affects the cost of the balancing process.

Fractional Horsepower Dynamometer

. . . accurately measures low torque values

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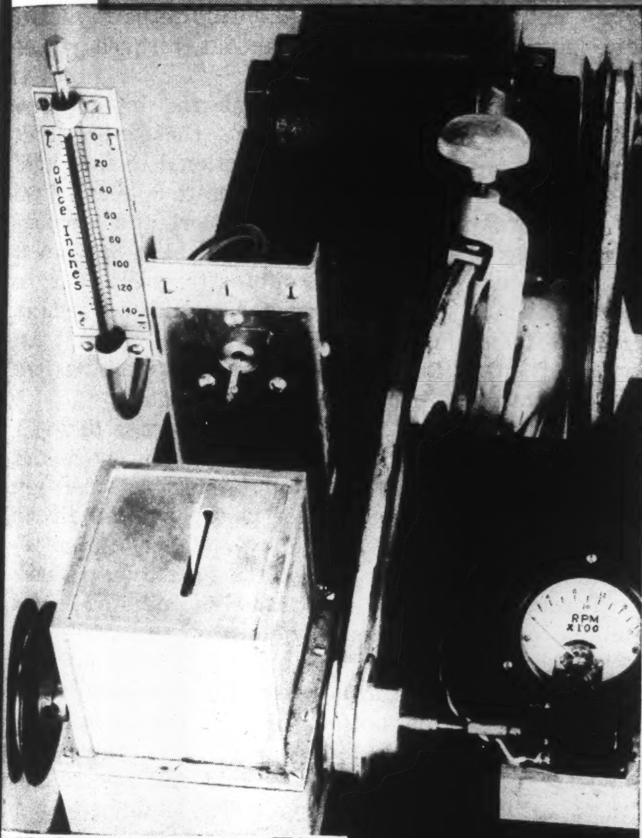

Fig. 1—Above—A unique hydraulic gage measures torque output of the dynamometer. Loads may be belted or coupled directly to the output shaft

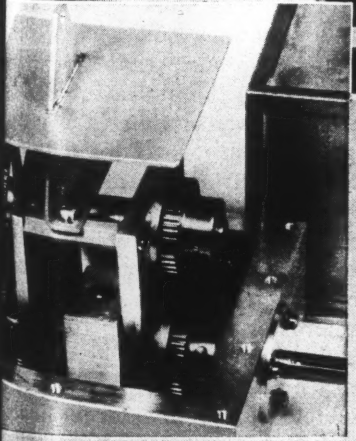

Fig. 2—Left—Gear transmission of the dynamometer consists of fabricated and machined steel parts. Baffle plate on the torque arm prevents oil splash through the top cover opening

DEVELOPMENT of instruments with rotating components often requires that the relatively small amounts of power needed to drive them at various speeds be determined with reasonable accuracy. For measuring torque at various speeds in connection with the adjustment of friction brakes in special instruments, the fractional horsepower dynamometer shown in *Fig.* 1 was developed. This unit is capable of measuring torques of 0 to 140 ounce inches over a speed range of 200 to 1800 rpm and from 0 to 0.2-hp, 0.2-hp representing a torque of 112 ounce inches at 1800 rpm.

The dynamometer assembly shown in *Fig.* 1 consists of: a ¼-hp 110v ac motor driving a V-belt speed-changer; a gear transmission dynamometer unit driven by V-belt from the speed changer; an electric tachometer; and a hydraulic torque indicator. Output of the dynamometer is taken from the pulley seen in the lower left hand corner of *Fig.* 1. Alternatively, the load may be connected through a positive drive flexible shaft attached to the output shaft. When the pulley takeoff is used, belt slippage, of course, is not permissible.

The speed changer, manufactured by Standard Transmission Equipment Co., gives continuously variable-speed output over a range of 4½ to 1 times the input speed. This speed variation combined with the use of two different sized sheaves on the motor output shaft produces overlapping speed ranges of 200 to 900 and 400 to 1800 rpm, an overall ratio variation of 9 to 1.

The gear transmission unit is shown in *Fig.* 2 with the cover removed to expose the gearing and frame construction. Operation of the dynamometer will be

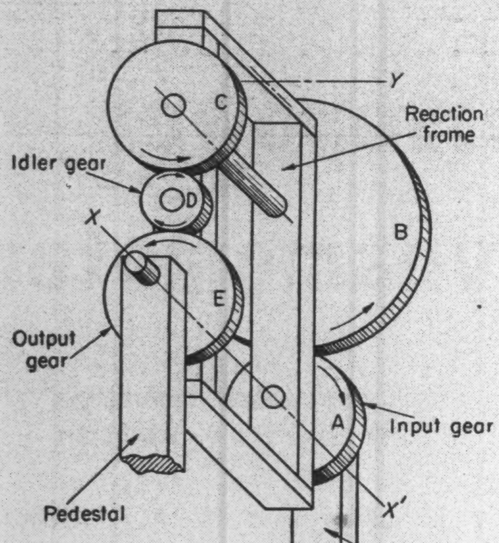

Fig. 3—Input and output shafts of the dynamometer also act as pivots for the reaction frame

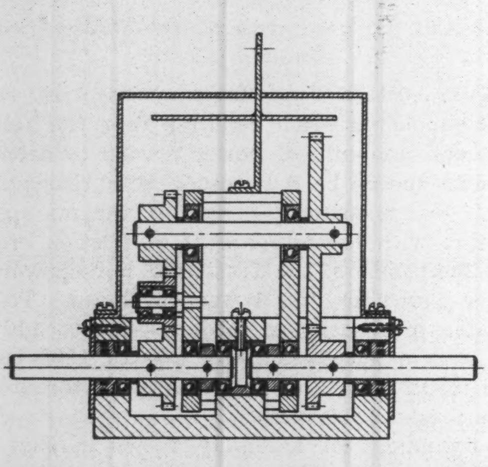

Fig. 4—Extensive use of ball bearings minimizes friction loss in the gear transmission and frame suspension alike. Drag of O-ring seals is negligible

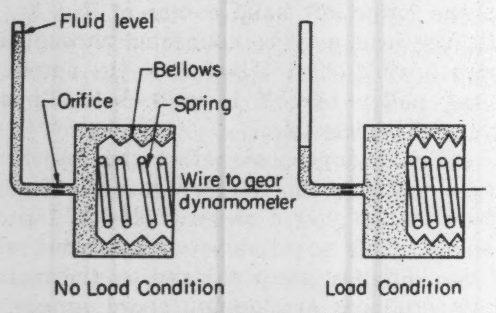

Fig. 5—Fluid column oscillations in the torque indicator gage are damped effectively by a small orifice in the tube line

understood readily by referring to the schematic diagram, *Fig.* 3. Gear *A* is mounted on the input shaft; gear *E* is on the output shaft. Both shafts are supported on fixed pedestals and have a common centerline, *XX'*. These shafts function as pivots for the rigid frame which supports gears *B, C* and *D*. Gears *B* and *C* are keyed to a common shaft which rotates in bearings on the frame. Gear *D* is a reversing idler which rotates on a stud mounted on the frame.

Input gear *A,* being driven clockwise, imposes a clockwise force to the frame through gear *B* and its shaft bearing. Output gear *E* driven counterclockwise against the load, also produces a reacting clockwise force in the frame through gear *D*. To hold the pivoted frame in vertical position, a counterclockwise force on the frame is required. This force represents the sum of the input and output torques applied through the gears and frame.

The output torque is equal to the input torque times the reduction ratio. Hence, the force to hold the frame in equilibrium is proportional to the output torque. If the idler gear *D* were omitted, gears *A* and *E* would rotate in the same direction, and the force to hold the frame in position would be a measure of the difference of input and output torques; thus, the sensitivity of the dynamometer would be reduced. Also, with idler gear *D* omitted, and an over-all gear ratio of unity, there would be no net reaction force on the frame, if friction were disregarded.

The tachometer, lower right-hand corner of *Fig.* 1, is a permanent-magnet generator driven by a short flexible shaft from the input side of the gear dynamometer. The generator voltage varies directly with speed and is measured by a dc voltmeter calibrated to read output rpm of the gear dynamometer.

Torque reaction in the frame is measured by a unique hydraulic indicator, shown on the left side of *Fig.* 1 between the gear dynamometer and motor. A wire from a torque arm on the dynamometer frame is fastened to the bottom of a bellows-shaped cup sealed in a housing; the space between the bellows and the housing is filled with fluid and is connected to a calibrated draft gauge. The fluid circuit is shown in *Fig.* 5. The torque arm pulls against the resisting force of the bellows and a coil spring, the combined spring constant being such that there is ¼-inch of travel for full range on the indicating scale. The indicating scale behind the glass tube is adjustable so that the readings are true net torque output. An orifice plug with a No. 80 drill hole is provided in the line between the spring chamber and the glass tube to damp out oscillations induced by high spots on gears and torque variations at the output. Torque indications read in ounce inches of torque supplied at the output of the dynamometer, the values for calibration being established by utilizing the pulley on the output shaft as a prony brake.

Readability and reproducibility of this torque indicator are within plus or minus one ounce inch; estimated accuracy is within plus or minus one ounce inch for any speed within the range of the dynamometer. Mounted on a 13 by 24-inch base of ¾-inch plywood, the entire dynamometer assembly is self-contained and easily portable.

High-Capacity Gearing

Gear design for transmission of maximum power in minimum space

Today the realization of the highest possible capacity in gear drives entails some departures from traditional and conventional concepts. Modern gear design can be surveyed from four points of view:

What is the current status and what recent gains have been registered in different fields of gear application?

What are the basic criteria in the design of high-capacity gears?

How can most judicious use be made of the conditions existing or imposed in a particular application?

What effects do basic gear manufacturing processes have upon the performance and, therefore, the design of gears for high power transmission?

These questions are answered in this comprehensive summary of today's best gear design practices.

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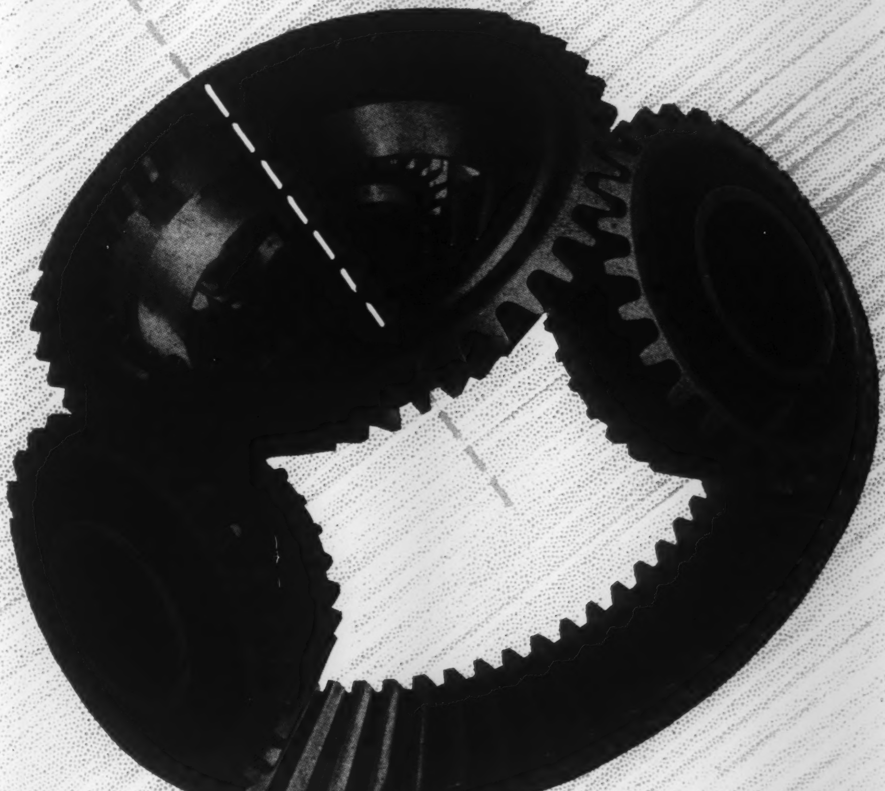

High-Capacity Gearing

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FOR transmission of rotating-shaft power with torque and speed conversion at a fixed ratio, gears are frequently the only practical means in the high power range. Gear drives are superior to other means of power transmission with respect to efficiency, cost, weight, and space requirements, when a constant ratio is required or permitted. TABLE 1 gives some comparisons but they are not to be considered generally applicable, since the values diverge greatly with changing power and speed ranges.

Although design and development of gear drives for high power ratings involve extensive engineering studies, the final product is still of comparative mechanical simplicity and its performance in service may be predicted satisfactorily before actual operation or test. Gear design and manufacture, in general, are old arts, but for the requirements of modern machines the scope of analysis, detail design, and test techniques have had to be extended far beyond the considerations acceptable only a few years ago. Results obtained by the aircraft industry and by certain groups in the marine propulsion field have revealed greater possibilities for the application of high power gearing. During World War II, a barrier existed between continents, obstructing the exchange of engineering developments between countries. Over that period extensive progress was made on both sides of the Atlantic, each side sometimes following different lines of development and bringing results that have not yet been exploited. One most important development of foreign origin took place in gear grinding equipment. Size limits have been greatly expanded and standards of quality previously unapproached can be achieved. As a consequence the designer can apply the high strength of carburized steel together with the accuracy of high

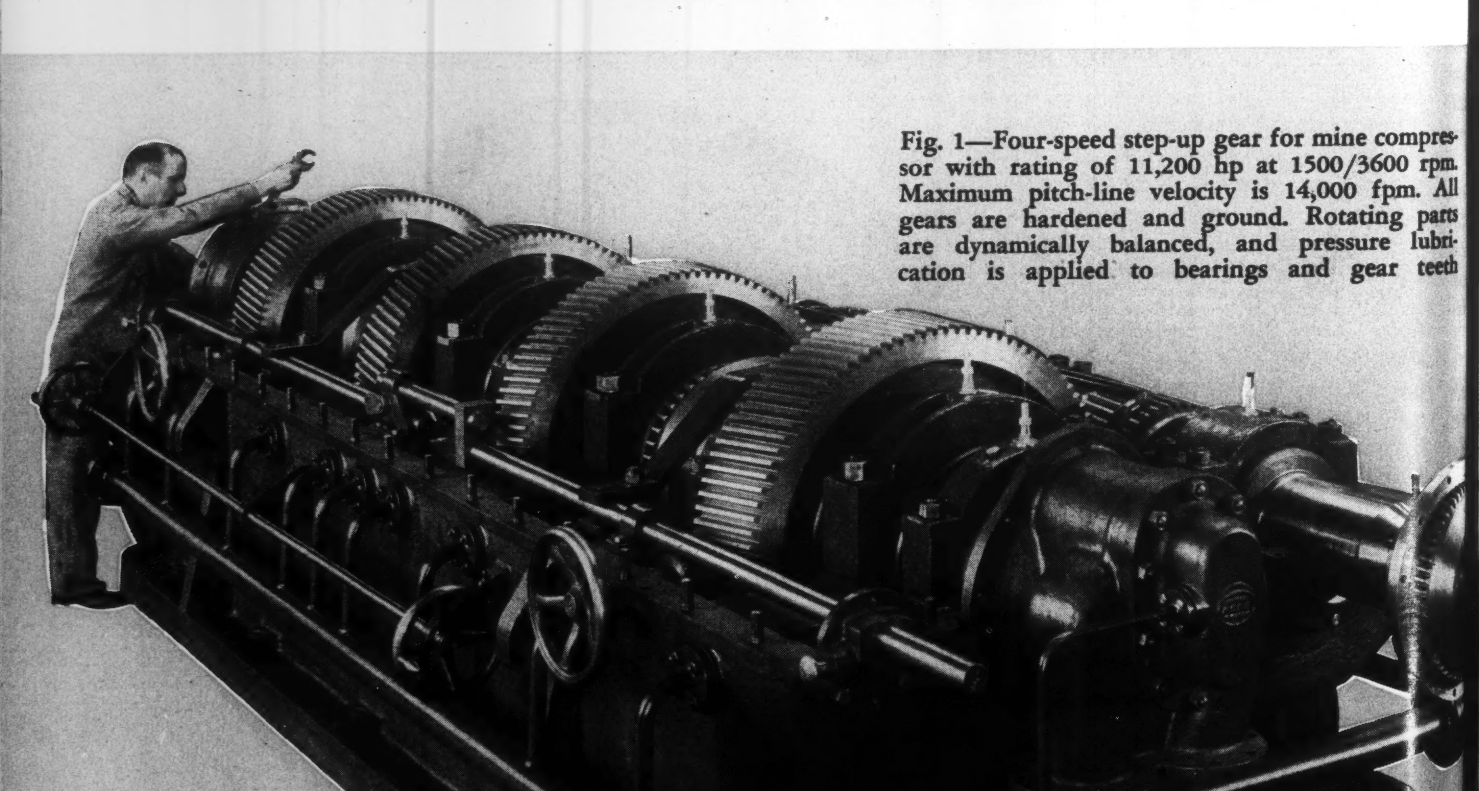


Fig. 1—Four-speed step-up gear for mine compressor with rating of 11,200 hp at 1500/3600 rpm. Maximum pitch-line velocity is 14,000 fpm. All gears are hardened and ground. Rotating parts are dynamically balanced, and pressure lubrication is applied to bearings and gear teeth

precision gears to drives of any power rating. Size and weight are reduced and advantages are gained in the overall application. Such more recent developments, rather than basic principles of gear engineering, shall be emphasized in this article.

Performance requirements for power transmission gears vary with the type of application. Where best engineering is applied, the designs for two gears used in two different applications will show few common features, even if the nominal power and speed ratings are the same. These differences show up when some of the most representative types of gear drives are compared.

Industrial Gears: Most industrial gear transmissions are made to liberal quality specifications, with greatest emphasis on resistance to rough handling, and simple maintenance. During recent years, however, some manufacturers have found it favorable to work to higher standards of engineering and workmanship, and obtain benefits from reduced weight and volume. On large installations this philosophy has proved to be particularly justified, *Fig.* 1.

For low power ratings, gears are usually made to standard dimensions and designed well above the rated load requirements. Materials are carbon steel, cast iron of 25,000 psi ultimate tensile strength, and other materials of lower strengths, such as bronze, laminated plastics, etc.

Automotive Gears: At this time, automotive gears are the result of extensive studies and tests, and have reached as high a degree of quality and uniformity as is consistent with the mass production requirements of that industry. Actually, one objective of research and test work on automotive gears was the determination of the minimum quality level that would still conform to operational requirements. American automotive transmission manufacturers have eliminated the grinding of gear teeth after final heat treating for manufacturing economy, while some European manufacturers grind their gears to high precision tolerances. This difference is influenced by the high operating speeds of some European engines, particularly in small cars, and by the generally superior uniformity of alloy steels in this country and better repetitive results with large lots of heat-treated gears. Typical materials for automotive gears are low-carbon chrome-nickel and chrome-molybdenum steels (SAE 2315, SAE 2515, SAE 4620), case hardened 0.030 to 0.040-inch case depth, 60 Rockwell C case hardness, and about 28 C to 35 C core hardness.

Table 1—Comparison of Power Transmissions

Type	Typical Efficiency (per cent)	Max Efficiency (per cent)	Relative Cost*	Relative Weight*
Gear Drive	98.5	99.2	1	1
Hydraulic Torque Converter.	70	90	3	4
Electric Motor-Generator Set	80	92	4	6

*Cost and weight increase with ascending numbers.

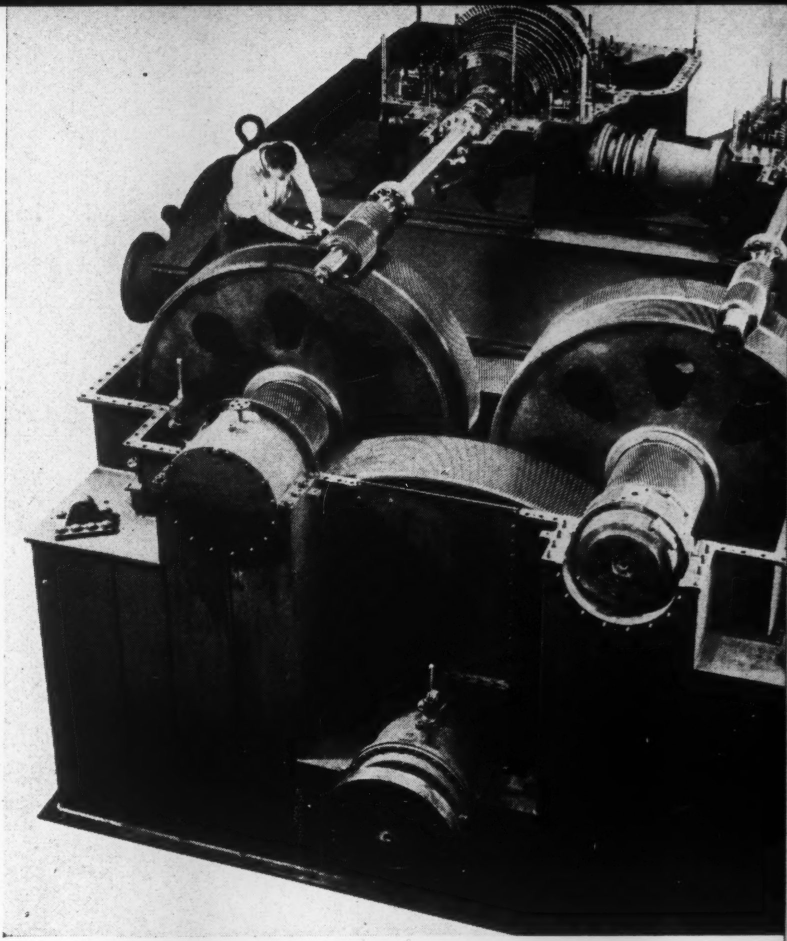


Fig. 2—Marine turbine reduction unit rated at 9000 hp

Design criteria for automotive gears were evolved from extensive records of the operating conditions and from fatigue tests intended to determine the smallest adequate size of gear. When automotive gears are compared with gears used in other types of equipment, their size usually appears small. However, automotive gears, particularly on passenger cars, operate during the greater part of their service life at only a fraction of the engine power.

The design of an automotive gear is based on the following requirements:

1. Sufficient static strength in the gear teeth to prevent breakage under the highest possible load. This would be a short-time peak load occurring

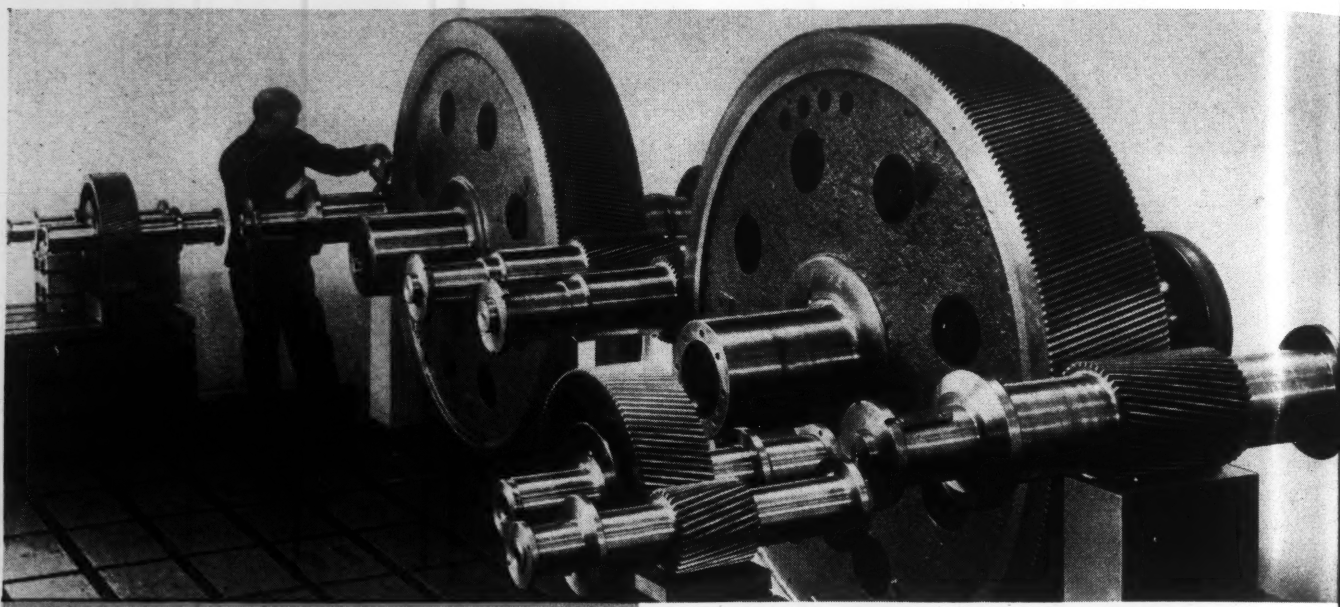
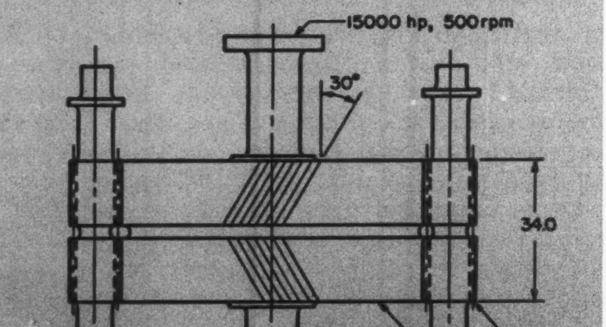
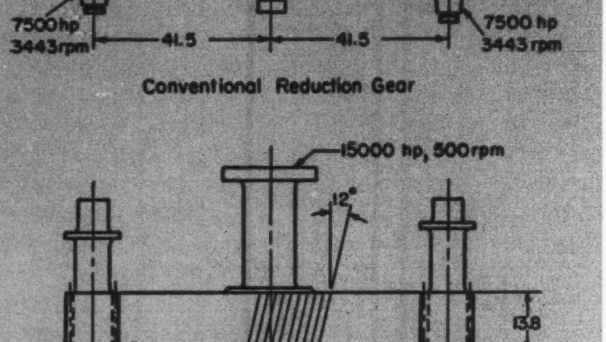


Fig. 3—Above—Carburized and precision-ground gears for a large marine drive, 15,000 hp per set, 30,000 hp total, 3443/500 rpm forward, 1600/232 reverse. Pitch-line velocity is 10,000 fpm

Fig. 4—Below—Comparative data for a conventionally designed gear set and an equivalent redesigned high-capacity reduction gear



Conventional Reduction Gear



High-Capacity Reduction Gear

only occasionally, such as when the vehicle hits a road obstacle.

2. Resistance to fatigue failure over the normally expected service life of a typical vehicle.
3. Sufficiently vibration-free and noiseless operation of the vehicle.

The first requirement is usually met by the basic design of the gear and by the strength limits of universal joints and drive shafts. Accurate values of peak loads are difficult to determine because of the great variety of service conditions, and the safety requirements in this respect are not as uncompromising as in marine or aircraft drives.

Fatigue resistance of automotive gears has been the object of extensive tests. Results indicate that during the life of a passenger car, the low gear is adequate for only about one to two hours of operation at full engine power. The reverse gear generally is used even less. The rear axle drive, while operating at all times of actual driving, runs only a small fraction of its time near full power; many automobiles are never driven at full engine power. The basis of the fatigue life calculation consists of (1) determining on the basis of previous service records and reasonable assumptions the percentages of full power at which the gear will operate for certain periods during the life of the vehicle, (2) converting these data to an equivalent time at which the gear would operate at full power, and (3) comparing the calculated stress in the gear tooth with the stress that will still insure adequate fatigue life.

Although smooth operation of automotive gears is a standard requirement, the problems in this field are not as serious as in many other gear applications. Transmission gears in automotive vehicles usually operate without power when in high gear and thus without noise. In low gear, a certain amount of gear noise is generally acceptable. Rear axle drives are frequently of hypoid design which operate at high sliding speeds (somewhat the same as worm drives) and inherently tend towards smooth operation. Most essential for quiet running are accuracy and uniformity of manufacture. These subjects will be discussed later in this article.

Since automotive gears are hardened after all machining operations are completed, their accuracy is limited by heat-treating distortions. Generally, they are held within 0.002-inch and these limits are found to be suitable for general automotive applications.

Marine and Turbine Reduction Gears: Speed reduction units needed for turbine prime movers have led to the development of this type of gear. Typical input speeds are 3000 to 12,000 rpm and output speeds range usually between 500 and 1500 rpm for stationary drives, 80 to 500 rpm for marine drives. *Fig.* 2 shows a 9000-hp turbine gear unit.

Marine drives usually present more serious problems to the designer, since space and weight are often restricted and operating conditions are, at times, extremely severe.

Power range for drives of this type include the highest values used in any field. Parallel shaft arrangements are predominant, but recently some outstanding designs were produced of the planetary concentric type.

Until recently, design criteria for these gears were based on the available methods of manufacture, which imposed stringent limits on the calculated permissible gear stresses. Because of the large size of these gears, hardening after the final machining process would have produced excessive distortion, and gear tooth grinding machines large enough are not produced

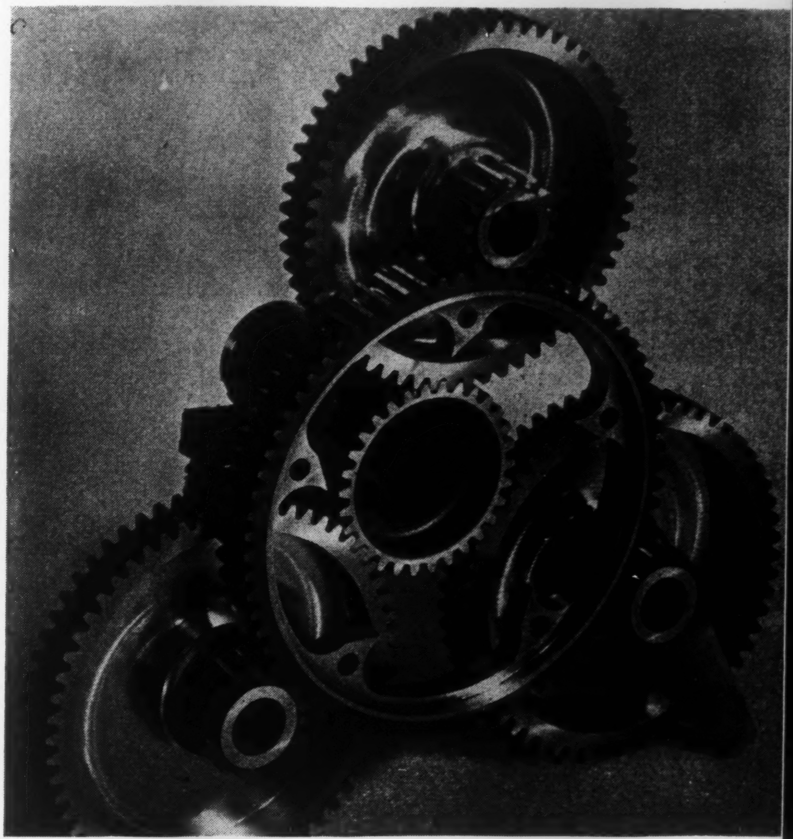
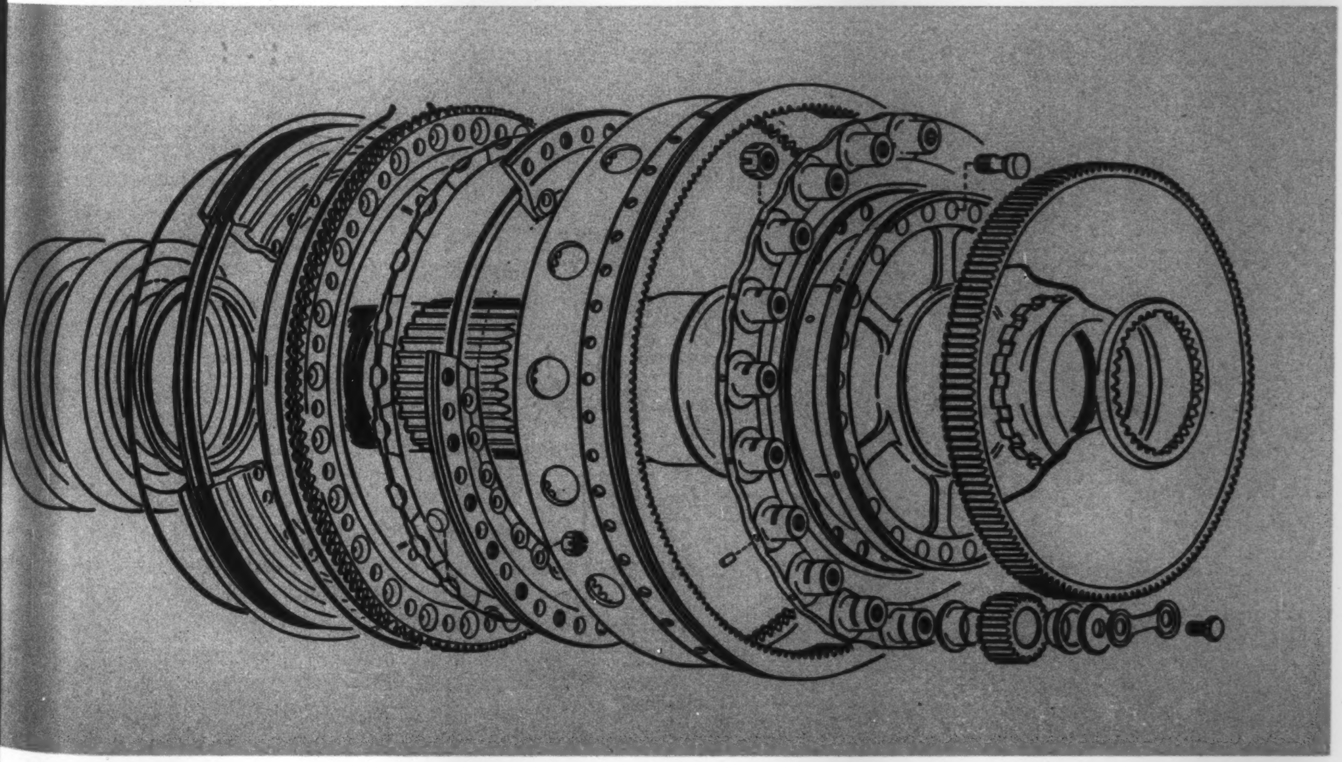


Fig. 5—Above—Aircraft engine supercharger drive gears for 2000/25,000 rpm. Accuracy of the hardened and ground gears permits triple-mesh arrangement with uniform load distribution

Fig. 6—Below—Planetary reduction gear of a reciprocating aircraft engine



in this country. As a result, American manufacturers of large gear drives use materials that are soft enough for cutting (to about 350 bhn). Sometimes, the teeth are shaved after cutting to improve surface finish. The great advantages in wear resistance and fatigue strength obtained by carburizing can not be realized in this method of manufacture. In recent years, machines for grinding large gears were developed abroad, and the results obtained with carburized and ground marine gears were most encouraging; *Fig.* 3 shows gears of this type.

Recently, a European manufacturer was requested to prepare a counterproposal for a reduction gear designed by conventional methods. The original set had been heat-treated alloy steel of 200 bhn for the gear and 240 bhn for the pinions. The manufacturer produced a new transmission with carburized and ground teeth. Although of equal power capacity, the new set weighs only 15 tons compared with 30 tons for the old unit. If reduction of the center distance had been permissible, the size and weight of the new unit could have been further decreased. Basic design data for the set are shown in *Fig.* 4.

Noise reduction is an acute demand on speed reducers for modern warships, because of danger of discovery by submarines. Here, too, the advantages of hardened and ground gears became apparent. The greater strength of the carburized gear permits reduction of the gear diameter, resulting in lower surface speed which tends to reduce noise. Uniformity of the gears is most essential for noiseless operation; generally, gears with a spacing tolerance of 0.0002-inch tooth-to-tooth, and accumulated spacing tolerances of 0.002-inch, will run practically silent up to surface speeds of 280 fps which is not to be considered a definite limit. Gear case, bearings, supporting structure, and lubrication system also influence operating noise.

Planetary reduction gears for large marine applications were developed in recent years, and test results are most promising. Their designs show many new principles which will influence the trends in other

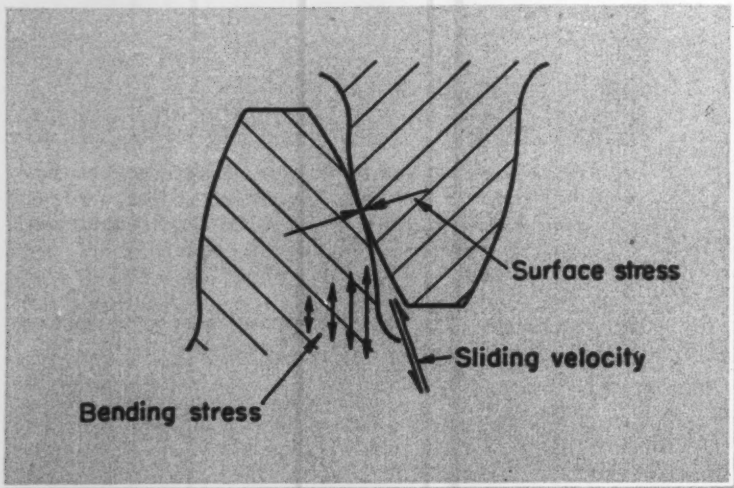
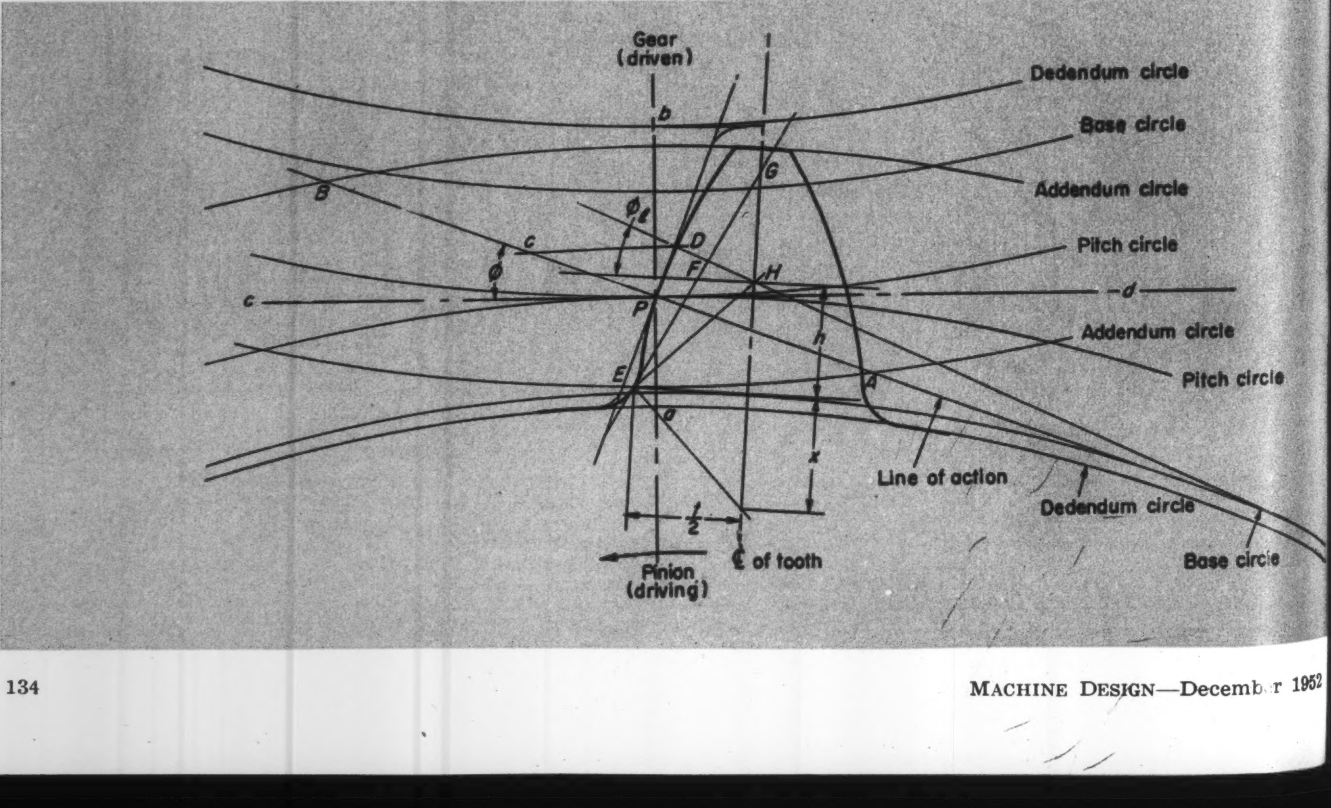

Surface stress
Sliding velocity
Bending stress

Fig. 7—Left—The principal limiting factors of gear tooth capacity

Fig. 8—Below—Diagram for calculation of bending stress in a gear tooth


Gear (driven)
1
b
Dedendum circle
Base circle
G
Addendum circle
B
ϕ_ℓ
c
D
Pitch circle
ϕ
F
H
c
P
d
h
Addendum circle
Pitch circle
E
A
a
x
Line of action
Dedendum circle
$\frac{t}{2}$
℄ of tooth
Pinion (driving)
Base circle

lines. Here again, the accuracy of ground gears is required in order to assure uniform distribution of load over the radially arranged planet pinions. Gear drives for this application are almost exclusively designed with sleeve bearings. The main reason is that such bearings have practically unlimited life, and will thus better fit into the long range service requirements of marine and utility installations. Type of gears used is not particularly sensitive to small displacements of the shafts and small wear of the sleeve bearings will not materially affect the operation of the gears.

With application of carburized and ground gears, and lightweight planetary designs entering the field of marine gearing, these units assume some resemblance to aircraft gears.

Aircraft Gears: For aircraft service, gears are made in almost as great a variety as in any field of industry, because of the great variety of aircraft drives. In all gear drives in this field, high speeds are involved and high loads must be transmitted by gears of small size. These conditions restrict the types of gears to those which make efficient use of gear tooth material, such as regular spur and helical gears for parallel shafts, and straight, oblique, and spiral bevel gears for intersecting shafts. Worm gears, straight and globoid, and hypoid gears have found little application in aircraft drives due to the high sliding velocities of the teeth in operation. Sliding results in low efficiency with accompanying power loss and necessity for extensive cooling. Otherwise, smooth operation and high gear ratio obtainable with a worm drive would be very desirable features.

The range of power and speed ratings, and the type and arrangement of gears used, change with the application. Generally aircraft gears can be classified in four groups which are not distinctly separate but which show certain individual design features.

ACCESSORY DRIVE GEARS: In Europe, the term "accessory drive" applies only to drives for additional equipment, while American manufacturers apply it also to drives that are necessary for the basic operation of the engine such as fuel pump and magneto drives. Speed range of accessory drives is around 3000 rpm in reciprocating engines, between 3000 and 15,000 rpm in gas turbines, and power is about 5 to 30 hp. The type of gear used changes with the individual application. Design criteria for these gears are, in principle, determined by the load characteristics of the driven unit which may be different from those of the engine. Frequently, the strength of the gear teeth on accessory drives is determined by certain extreme conditions, such as congealed oil at low temperature for a lubricating oil drive or shock loads for a starter drive. Sometimes the arrangement of the drive itself requires gears larger than the permissible minimum, for example, if center-distances must be met, or if an additional gear must be interposed to obtain a certain direction of rotation. Otherwise, considerations of beam strength, fatigue resist-

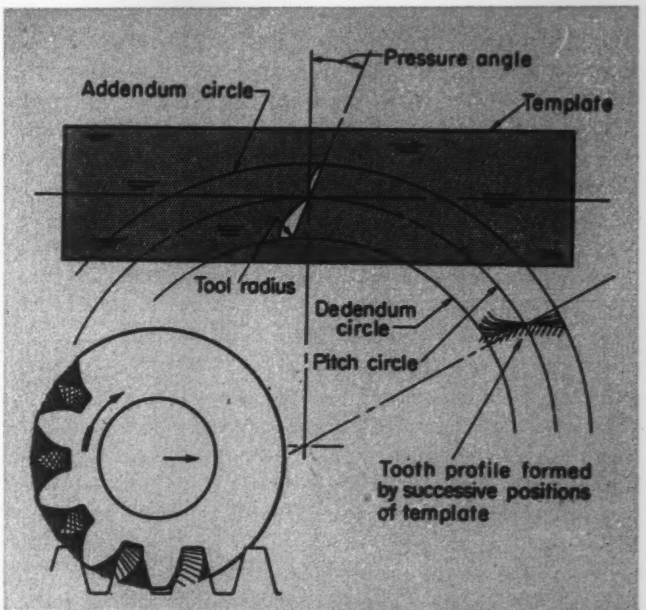


Fig. 9—Diagram for developing tooth form

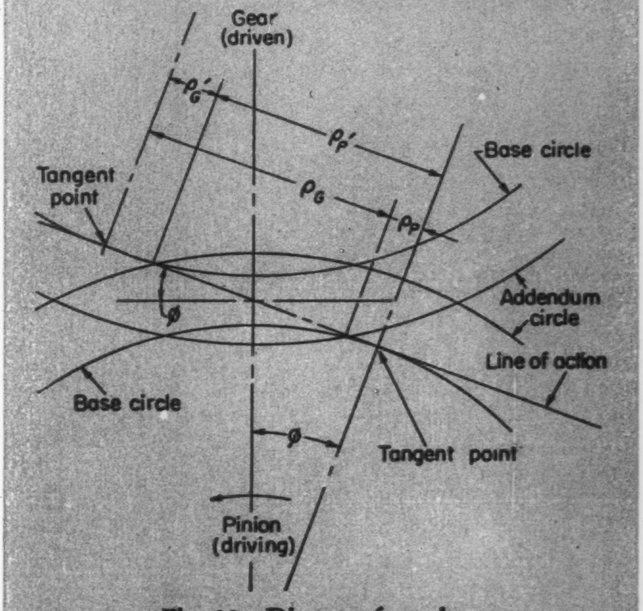


Fig. 10—Diagram for calculation of sliding velocity

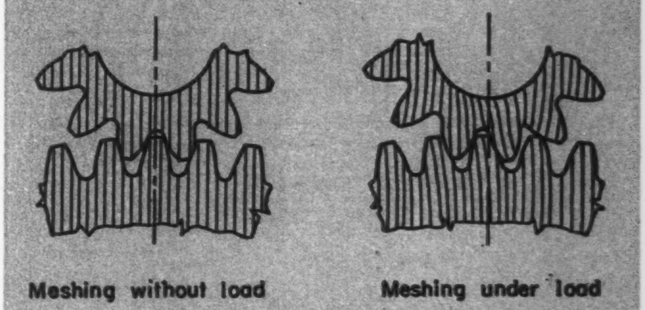


Fig. 11—Gear tooth deflections due to operating load

ance, and surface loading apply similarly as on main drive gears.

Supercharger and Compound Engine Gears: Superchargers for reciprocating engines are either driven by exhaust gas turbines, or from the crankshaft over speed increaser gears. Typical supercharger speeds are 15,000 to 30,000 rpm. *Fig.* 5 shows a set of supercharger drive gears for 2000/25,000 rpm.

If the design of the engine is such that a greater part of the power is delivered in form of exhaust gas to a turbine, this power is then delivered back to the crankshaft over the drive gears. A typical engine of this type is the Wright Compound, which uses three exhaust turbines and delivers power back to the crankshaft over gears with interposed fluid couplings to eliminate torsional vibrations. Another example is the Napier Nomad, a diesel-gas turbine combination with dual counterrotating propellers, one driven by the reciprocating section, the other by the gas turbine.

The high speeds involved in this type of gear drive create particularly strict requirements for accuracy and uniformity of the gears.

Propeller Reduction Gears: Weight reduction tendencies in aircraft engines have brought crankshaft speeds into the 3000-rpm range, while propeller efficiency makes the 2000-rpm range desirable. The result is the use of reduction gears on aircraft engines. Typical is the planetary drive arranged concentrically at the engine nose. The speed ratio of about 1.5 to 1 leads to large sun gears connected to the crankshaft by several small planet pinions arranged on the carrier which is connected to the propeller shaft. The stationary ring gear may be supported torquewise by hydraulic cylinders which then permit torque measurement by indication of the pressure in the fluid. *Fig.* 6 shows in exploded view a typical planetary aircraft engine reduction gear.

These planetary reduction gears developed almost as a special field with little contact with other gear developments. Problems of proper support of the gears in the light and flexible structures have led to preference of spur gears to avoid tilting loads on the pinions. Greatest uniformity is required from tooth to tooth, and from gear to gear, to assure uniform

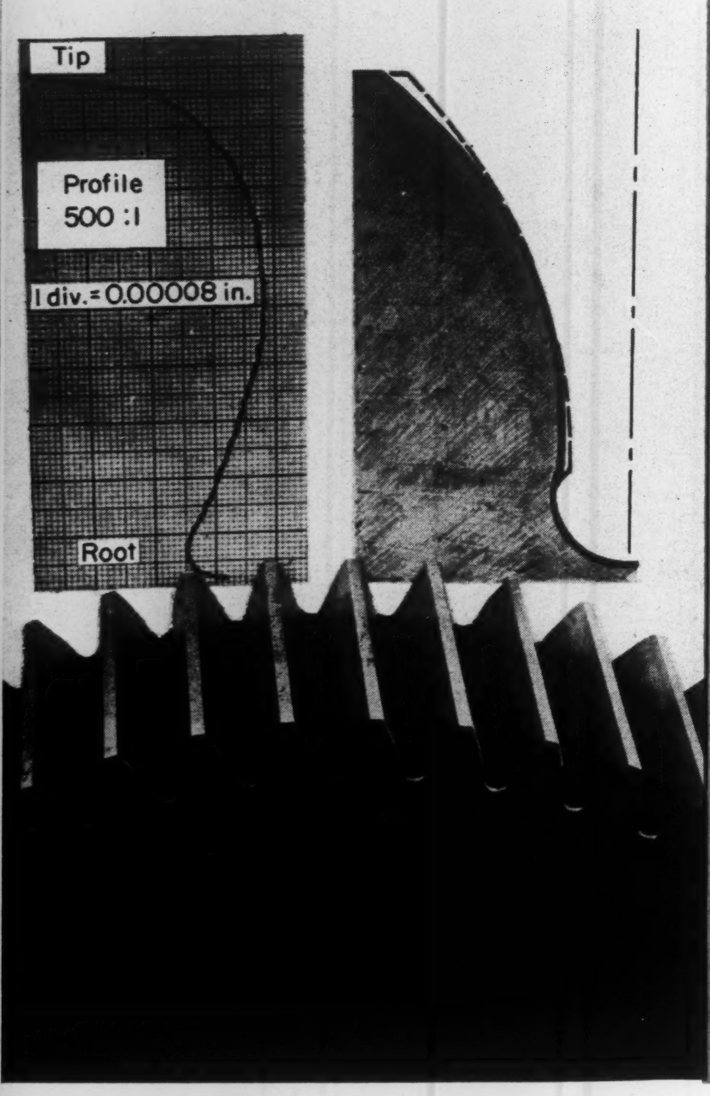


Fig. 12—Left—Diagram of gear tooth with ground flanks, incorporating tip and root relief of involute

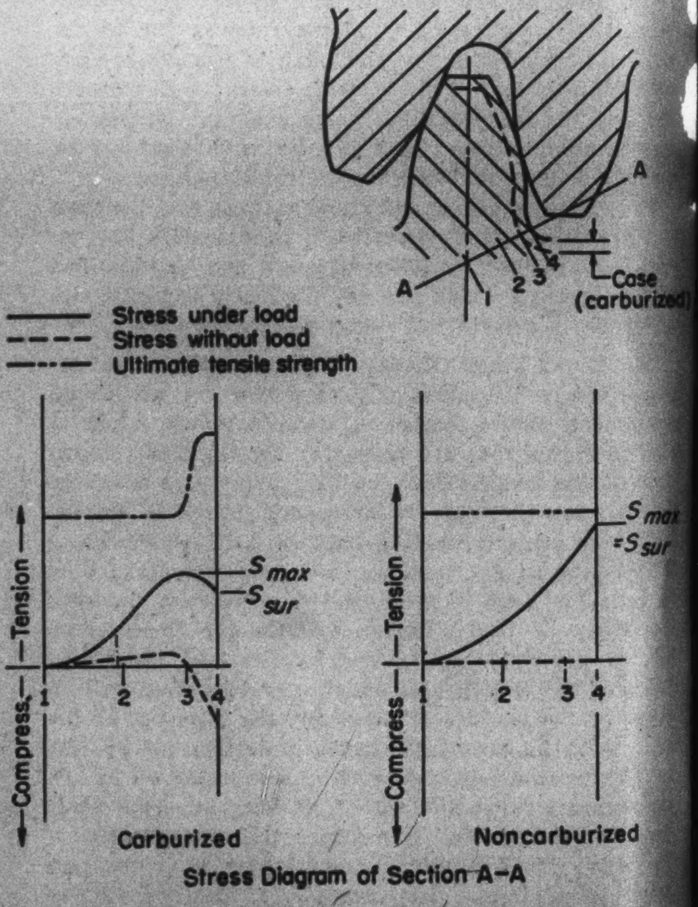


Fig. 13—Above—Diagram showing stress difference between carburized and noncarburized gears

distribution of loads. The design must make use of the flexibility of the thin sections to produce deflections that will tend to reduce the effects of any irregularity in concentricity or spacing of pinions.

Where the prime mover is a gas turbine, the reduction gear steps the turbine rotor speed of about 10,000 to 15,000 rpm down to propeller speed, about 1500 to 2000 rpm. This reduction may be obtained by two planetaries in series, or by a compound planetary. Where two power plants drive one propeller, additional spur or helical drives and free-wheeling clutches are used. On high-powered turboprop drives, the size of the gears, together with the high speeds, leads to surface speeds that approach the known upper range for gear operation. In this respect, however, it seems that with precision-ground gears of high surface hardness the safe limits may still be extended and the limitation for gas turbine speeds is still in the turbine rotor, with the gear drives today well in the conservative range.

High loads on the gear teeth, together with thin sections of the adjoining blank, lead to considerable deflections of the teeth. The effect of these deflections is a difference in the tooth spacing between the teeth that are just in mesh and under load, and the teeth that are just coming into mesh. The interference effected by this deflection may be eliminated by suitable modification of the form of the teeth, as will be shown later in this article.

HELICOPTER DRIVE GEARS: Helicopters with geared rotor drives use power plants of the same type as propeller-driven aircraft, and require further speed reduction and transmission to the lift rotors. Their gear requirements, therefore, include all of the previously mentioned aircraft gears, and also a large variety of other gears to fill the requirements for locational arrangement and high driving torque.

Typical helicopter rotor speeds are between 150 and 400 rpm, and with typical engine speeds of 2500 to 15,000 rpm for reciprocating engines or turbines, respectively, the overall gear ratio of helicopter drives ranges between 6 and 100. Part of the total gear ratio may be obtained in bevel gears where change of direction of the drive is required, and the balance

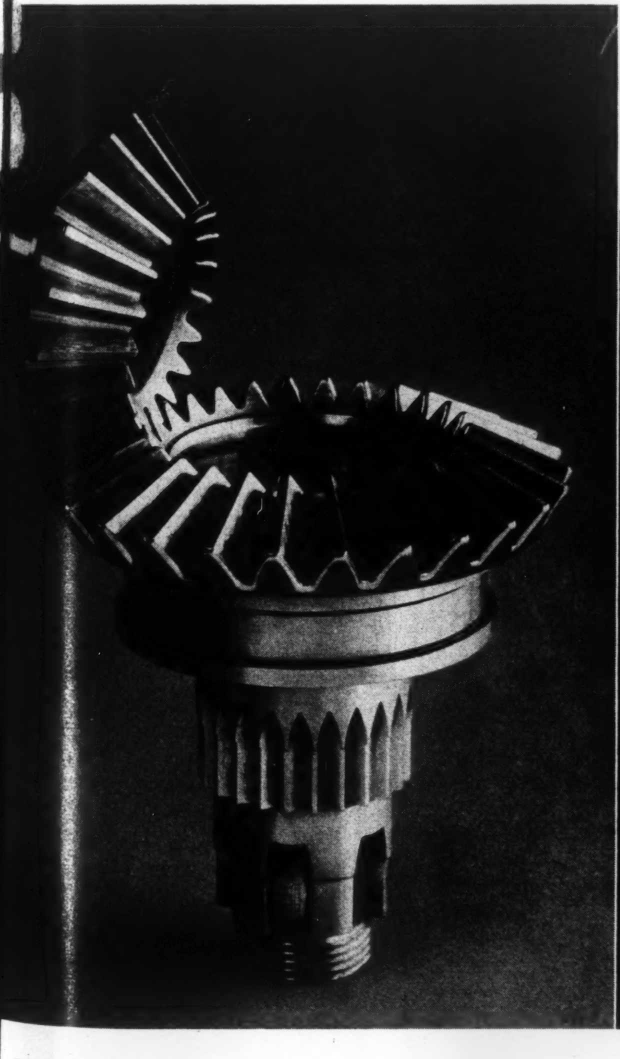


Fig. 14—Left—Radial-tooth bevel gears with precision-ground teeth

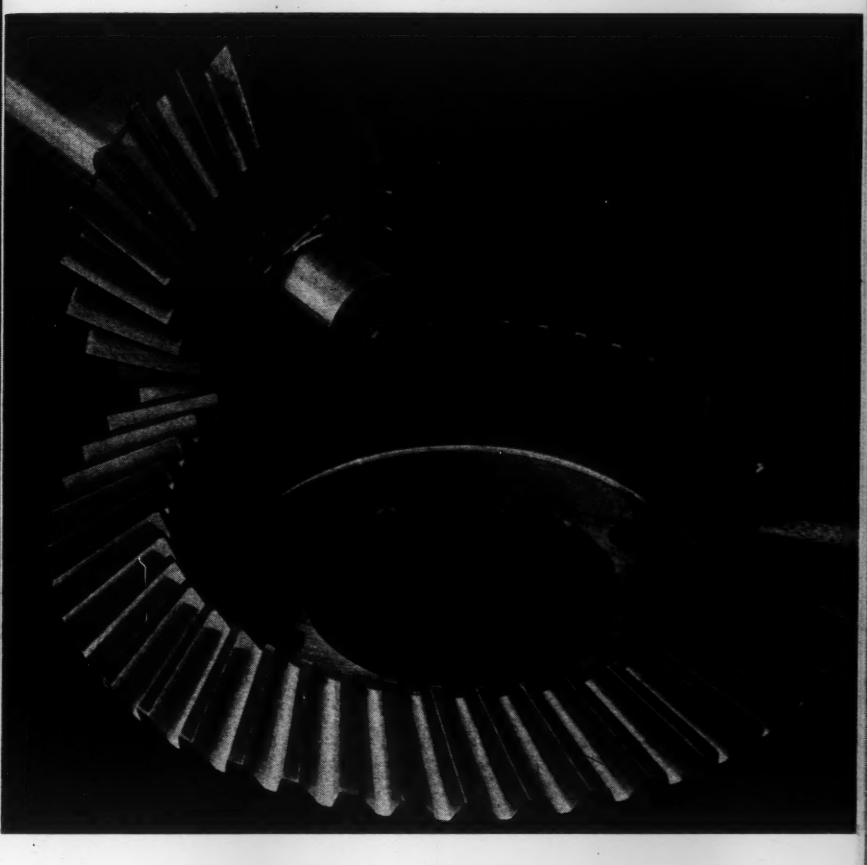


Fig. 15 — Below — Oblique-tooth bevel gears with precision-ground teeth

is usually applied by planetary drives.

Gears for helicopter drives are almost exclusively carburized and ground. Whenever an unground gear is used, the reason is lack of availability of grinding facilities, or failure to provide for grinding wheel clearance in the original design. In some cases, such difficulties have led to extensive research on unground gears aimed at increasing their power capacity to approach that of a ground gear of equal size. In all cases, results show that the high uniformity of a precision-ground gear cannot be dispensed with on any high-capacity gear drive. This requirement becomes even more essential with higher operating speeds. On planetaries, the advantage of the multiple-mesh condition can be realized only with precision-ground gears.

High-Capacity Gearing

POWER TRANSMITTING CAPACI

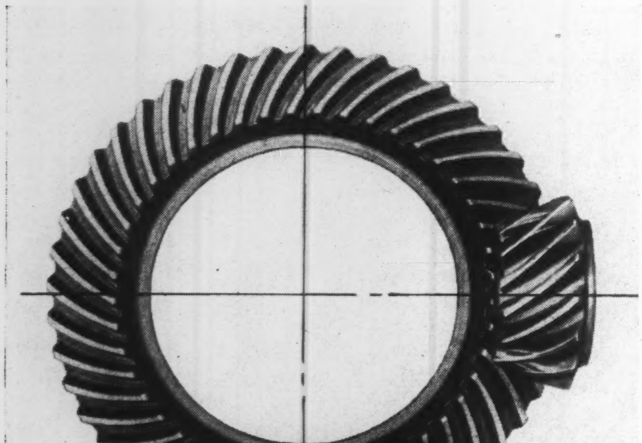


Fig. 16—Curved-tooth bevel gears, top, and hyperboloid (Hypoid) gears, bottom

Design limitations for a gear drive are usually determined by the gear teeth and bearings. All other parts can generally be made materially stronger without increasing the overall dimensions.

As with all engineering calculations, gear teeth are analyzed on the basis of simplifying assumptions which are more or less realistic depending on the arrangement of the gear mounting, the type of gears used, and the accuracy of the gear teeth. The experienced designer can estimate the degree to which a gear stress analysis can be applied to a given design. The greater the deviation from geometrical accuracy, the greater the possibility of load concentrations with resulting stress increases.

The scope of this section is restricted to material of practical use to the designer, and all theoretical data on basic gear geometry and stress analysis are omitted.

Simplified Design Equations: Analysis is based on the existence of a preliminary design, which is produced by estimates and previous experience. This preliminary design is then refined until, by trial and error, a final design is obtained. In order to facilitate preliminary design, formulas for determining dimensions of nearly final magnitude are presented here. They are based on existing theories, converted into readily usable practical form.

Power transmitting capacity is determined by three factors, *Fig.* 7:

1. *Bending stress of the gear tooth.* The cross section of the tooth is analyzed for bending stress as a cantilever beam, and the calculated stress is compared with a known permissible value. It must not exceed the permissible static bending stress, and since this stress occurs intermittently during the rotation of the gear, it must not extend into a range where fatigue failure during service may be expected.
2. *Surface stress on the tooth flanks.* The curved flanks under pressure during operation must not be exposed to a compressive stress that would produce subsurface shear failure in fatigue.
3. *Heat on the sliding surfaces.* Pressure on the tooth

flanks in conjunction with sliding velocity produces local heat, which must not exceed the amount which can be dissipated by conduction into the gear blank, radiation and convection to the outside and into the lubricant.

For given power and speed, the diameter of a gear becomes smaller with increasing face width. But since the tangential force on the pitch radius will tend towards unequal distribution on long gears, the limits for the face width are rather narrow. This is more pronounced on bevel gears where the pitch diameter changes with distance from the cone center. For a drive with given power and speed data, the pitch diameter for a spur pinion of a pair with carburized and ground teeth may be calculated from (see Nomenclature)

$$D_P = 6.1 \sqrt[3]{\frac{P}{n_P R} \, \frac{1 + m_G}{m_G}} \qquad (1)$$

Similarly for a helical pinion,

$$D_P = 5.4 \sqrt[3]{\frac{P}{n_P R} \, \frac{1 + m_G}{m_G}} \qquad (2)$$

The borderline between spur and helical gears, in terms of the proper application of Equations 1 and 2, is determined by helix angle ψ, face width F, and circular pitch p. Any gear whose helix angle is small enough not to give any "tooth overlap" should be calculated by the spur gear formula. For a spur gear, $F \tan \psi < p$. For a helical gear, $F \tan \psi > p$. Tooth overlap will beneficially affect stress distribution only if the pitch and profile errors are maintained within very close limits.

Also, for a straight-tooth bevel pinion (radial teeth), the pitch diameter may be calculated from

$$D_P = 9.2 \sqrt[3]{\frac{P \cos \gamma}{n_P} \, \frac{1 + m_G}{m_G \sqrt{1 + m_G^2}}} \qquad (4)$$

And, for a spiral-tooth bevel pinion (curved or oblique teeth),

$$D_P = 8.14 \sqrt[3]{\frac{P \cos \gamma}{n_P} \, \frac{1 + m_G}{m_G \sqrt{1 + m_G^2}}} \qquad (4)$$

From the method of calculating spiral bevel gears given by Gleason, the pitch diameter

$$D_P = 9.7 \left(\frac{P}{n_P \sqrt{1 + m_G^2}} \right)^{2/5} \qquad (5)$$

The values obtained with Equations 4 and 5 are approximately the same within the usual design range. For the bevel gear equations, it was assumed that $F = A/3$. This relationship of face width to cone distance holds within narrow limits in most high-capacity designs.

The number of teeth for a given pitch diameter calculated from these design equations is determined on the basis of bending stress. The smaller the number of teeth for a given pitch diameter, the larger the teeth and therefore the stronger the gear. Too few teeth would lead to rough operation. From the viewpoint of bending strength, a recommended maximum number of teeth for the pinion is

$$N_{P\text{-}max} = 25 \, \frac{1 + m_G}{m_G} \qquad (6)$$

Nomenclature

A = Cone distance of bevel gears, inches
D_G, D_P = Pitch diameter of gear and pinion, inches
E = Modulus of elasticity, psi
F = Face width, inches
h = See *Fig. 8*
K_c = Root fillet stress-concentration factor
K_{pv} = Heating criterion ("pv" factor)
m_G = Gear ratio ($m_G = N_G/N_P = D_G/D_P$)
N_G, N_P = Number of teeth in gear and pinion
n_G, n_P = Rotational speed of gear and pinion, rpm
P = Power, hp
P_d = Diametral pitch
p = Circular pitch, inches
p_b = Base pitch, inches ($p_b = \pi \cos \phi / P_d$)
R = Ratio of pinion face width to pinion pitch diameter ($R = F/D_P$)
s_b = Tooth bending stress, psi
s_c = Surface compressive stress, psi
T = Torque, lb-in.
t = Tooth width at critical section, inches
v = Linear sliding velocity, fps
W_t = Tangential tooth load, lb
x = See *Fig. 8*
Y_K = Tooth form factor including stress concentration
γ = Pitch angle of bevel pinion, degrees, ($\tan \gamma = D_G/D_P$)
ρ_f = Root fillet radius, inches
ρ_G, ρ_P = Profile radius of curvature of gear and pinion teeth, inches
ϕ = Pressure angle, degrees
ϕ_L = See *Fig. 8*
ψ = Helix angle, degrees

The foregoing equations are based on existing, generally accepted theories. Their compliance with practical performance data is somewhat limited and a number of essential characteristics of the gears were not introduced in their derivations. However, the equations quickly yield results which are usually accurate enough for preliminary design study. Graphical simplifications of the equations are presented in another article in this issue, Page 161. After the basic proportions of the gear pair are selected, detailed calculations must next be made against the three performance criteria: bending stress, surface stress, and heat.

Bending Stress: Particularly important for the strength of gear teeth and for the actual stresses occurring in them, are the dimensional and metallurgical properties of the stressed portions of the teeth.

The manufacturing processes used are of decisive influence. However, a complete picture of all dimensional deviations cannot be obtained, particularly not of the internal stresses caused by heat treating, or by certain grinding processes which operate with high local temperatures and liquid coolants. Therefore, the calculations must be supplemented by proper selection of permissible stress values which take into account the type and quality of manufacture and the characteristics of the application.

Calculations for bending stress in gear teeth are based on the simple cantilever beam theory. That theory is based on a linear stress increase from a neutral zone to the outer fiber, a condition which does not actually exist. However, as long as the permissible limit values are based on past actual performance, and the method of calculation is uniform for all cases, the calculated stress may be used as a reference figure for comparison. All bending stress calculations are based on a spur gear, and helical or bevel gears of any kind are calculated as equivalent spur gears.

The bending stress calculation involves the geometry of the involute which is necessary in finding the point where the load is applied, and the magnitude of the section modulus. A recommended calculation procedure is given here point by point. Where pinion and gear teeth are of equal circular thickness, addendum, and whole depth, and of the same material, only the pinion need be analyzed since its bending stress will be higher than that of the gear. Otherwise, both pinion and gear must be analyzed.

LAYOUT PROCEDURE: A layout of pinion and gear teeth is made most conveniently to a scale of one diametral pitch. For example, to scale the layout of a gear having a diametral pitch of 8, all dimensions must be multiplied by 8.

Lay out the pitch circles, the addendum circles, and the dedendum circles for a pinion and gear, *Fig.* 8. Draw the line of action through the pitch point P at the pressure angle ϕ.

Contact of the gear teeth starts at point A, the intersection of the line of action and the addendum circle of the gear. Contact ends at point B, the intersection of the line of action and the addendum circle of the pinion.

Draw the base circles, whose diameters equal $D_G \cos \phi$ and $D_P \cos \phi$. The line of action is tangent to the base circles.

Make a template for generating the profile of the driving face of a pinion tooth, as follows:

Draw a line perpendicular to the line of action through the pitch point. This represents the position of the side of the generating tool for pitch point contact. The ends of the straight contour of the tool are determined by the intersection of this cutting edge with two lines tangent to the dedendum circles at points a and b. Draw the tool edge radius, adjoining at the ends of the straight contour. Scribe the side of the generating tool and the generating-tool pitch line cd which is a tangent to the pitch circle at the pitch point P. Remove a section of the template leaving the side and corners of the tool as shown in *Fig.* 9.

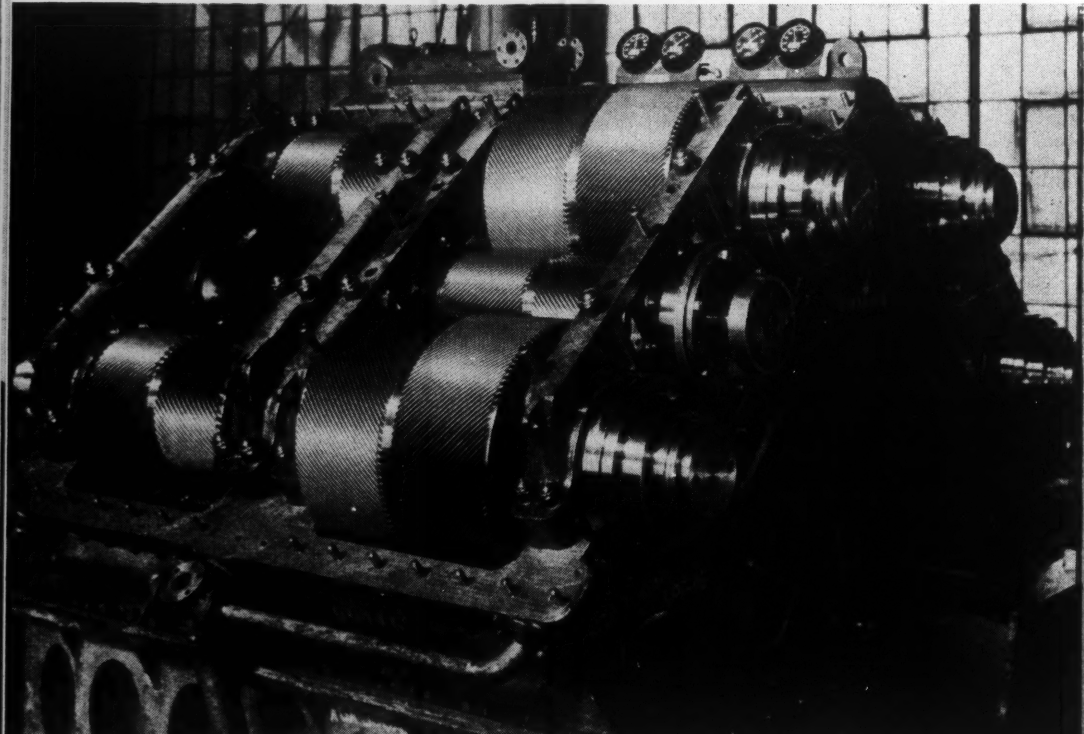


Fig. 17 — Left — Large marine reduction gear, driven by two steam turbines of 25,000 hp each. Input speed 6000 rpm output 250 rpm

Fig. 18—Right — Compact arrangement of a large turbine reduction gear unit

Generate the tooth profile by rolling the pitch line of the rack tool on the pitch circle of the gear, and at each position of the template draw the outline of the tool. Use pins to prevent slippage of the pitch line of the generating tool as it is rolled along the pitch circle.

Draw the radial centerline of the tooth, located $p/4$ distance (0.785-inch) along the pitch circle from pitch point P. Mark the circular base pitch AC along the line of action, starting at point A. At point C the highest single tooth contact occurs.

Rotate the point C about the center of the pinion to determine point D. Through point D draw a tangent to the pinion base circle as shown in the layout, *Fig.* 8.

Construct a perpendicular to the radial centerline of the tooth at the intersection of this tangent and the radial centerline. Draw EG tangent to the tooth fillet so that $EF = FG$. Draw EH. Construct EI perpendicular to EH.

CALCULATIONS: On the basis of a drawing such as *Fig.* 8, the bending stress is now calculated from

$$s_b = \frac{W_t P_d}{F Y_K} \qquad (7)$$

where

$$Y_K = \frac{1}{K_c \dfrac{\cos\phi_L}{\cos\phi}\left(\dfrac{1.5}{x} - \dfrac{\tan\phi_L}{t}\right)} \qquad (8)$$

For pressure angles of 20 degrees and higher,

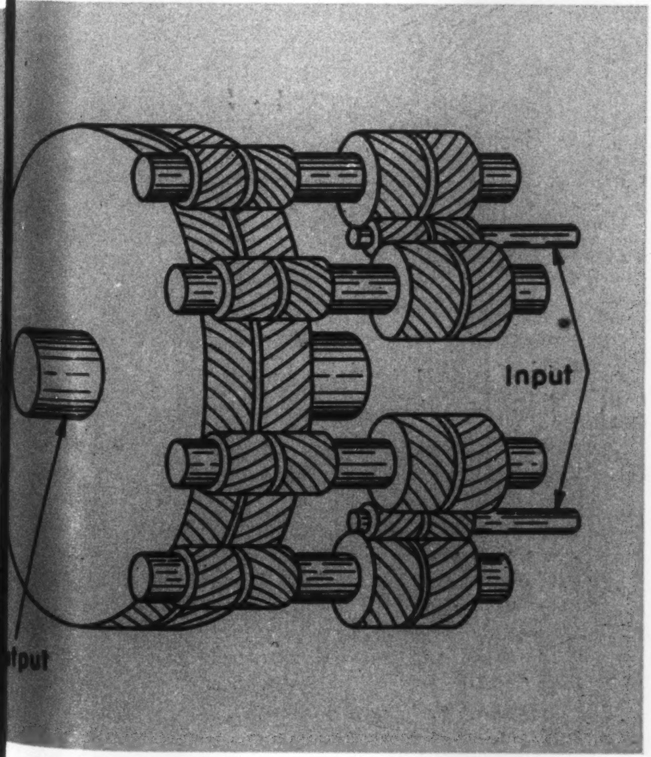
$$K_C = 0.18 + \left(\frac{t}{\rho_f}\right)^{0.15}\left(\frac{t}{h}\right)^{0.45} \qquad (9)$$

For pressure angles less than 20 degrees,

$$K_C = 0.22 + \left(\frac{t}{\rho_f}\right)^{0.2}\left(\frac{t}{h}\right)^{0.4} \qquad (10)$$

And the remaining term in Equation 7 is

$$W_t = \frac{2T}{D_P} \qquad (11)$$



Surface Compressive Stress: The compressive stress at the flanks is calculated on the basis of the Hertz formula which, for mating gears of the same type of material, becomes

$$s_c = 0.836\sqrt{\frac{W_t E}{D_P F \sin 2\phi}\,\frac{m_G + 1}{m_G}} \qquad (12)$$

and for steel gears (E = 30,000,000 psi) is

$$s_c = 4588\sqrt{\frac{W_t}{D_P F \sin 2\phi}\,\frac{m_G}{m_G + 1}} \qquad (12a)$$

Equation 12 gives the value of surface compressive stress at the pitch point. It is used for comparison with permissible values.

Heat: The heat generated during the mesh cycle is a function of pressure on the tooth flanks and sliding velocity. Both are variables, and only their maximum values are used to obtain a reference figure. Certain of the required factors are quickly determined by layout of the pitch point, base circles and addendum circles, *Fig.* 10. The common tangent on the base circles is drawn and its intersections with the addendum circles are marked. At the beginning of mesh action, the sliding velocity is equal to the difference of the rolling speed of the two profiles. These speeds are

$$v_P = \frac{n_P}{60}\,\frac{2\pi\rho_P}{12} \qquad (13)$$

$$v_G = \frac{n_G}{60}\,\frac{2\pi\rho_G}{12} \qquad (14)$$

At the beginning of action, the sliding velocity is

$$v = v_G - v_P = \frac{\pi}{360}\,(n_G\rho_G - n_P\rho_P) \qquad (15)$$

Similarly, at the end of action,

$$v' = v_G' - v_P' = \frac{\pi}{360}\,(n_G\rho_G' - n_P\rho_P') \qquad (16)$$

The "pv" value is the product of surface compressive stress and sliding velocity. Since the sliding velocity is zero at the pitch point, and increases to-

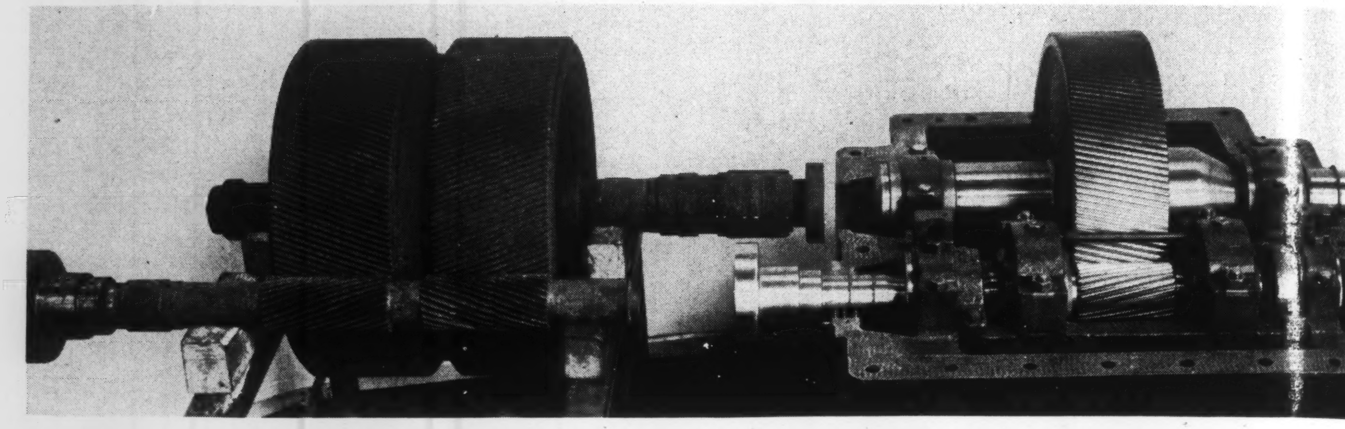


Fig. 19—Replacement of a cut gear set with carburized and ground high-capacity gears

ward root or tip, the "pv" value will be a maximum at either the beginning or the end of action.

The surface stress, at the beginning of action, is

$$s_c = 3240 \sqrt{\frac{W_t}{F \cos \phi} \frac{\rho_P + \rho_G}{2\rho_P \rho_G}} \qquad (17)$$

At the end of action it is

$$s_c' = 3240 \sqrt{\frac{W_t}{F \cos \phi} \frac{\rho_P' + \rho_G'}{2\rho_P' \rho_G'}} \qquad (18)$$

The "pv" value is

$$\begin{aligned} K_{pv} &= s_c v, \text{ or} \\ &= s_c' v' \qquad (19) \end{aligned}$$

whichever is the larger.

The magnitudes of ρ_P, ρ_G, ρ_P', and ρ_G' are obtained by scaling the layout, *Fig.* 10. If drawn to other than actual tooth size, adjustment for scale must be made, of course. Note that $\rho_P + \rho_G = \rho_P' + \rho_G' = (D_G \sin \phi + D_P \sin \phi)/2$.

Limit Values: After the reference figures for the gear stresses have been calculated, they must be compared with the known limit values obtained from tests or service reports. These values are dependent on the materials used, their metallurgical condition, accuracy and quality of manufacture, and design arrangement. No universal equation can be given for such limit values, but a number of representative examples, which cover a wide range of gear applications, are listed here for guidance.

Permissible bending stress in root fillet:

1. For continuous operation, alloy steel heat treated to 130,000 to 150,000 psi ultimate tensile strength: $s_b = 20{,}000$ psi.
2. For continuous operation, alloy steel (SAE 4620, 3312, or equal) carburized to 60 Rockwell C case hardness and 32 to 40 Rockwell C core hardness, teeth ground to a tolerance of 0.0005-inch maximum deviation from theoretical tooth-to-tooth spacing, and lead over face length not to deviate more than 0.0005-inch from theoretical angle: $s_b = 33{,}000$ psi.
3. Same as case 2 but for teeth precision ground by point-generating system to a tolerance of 0.00012-inch: $s_b = 40{,}000$ psi.

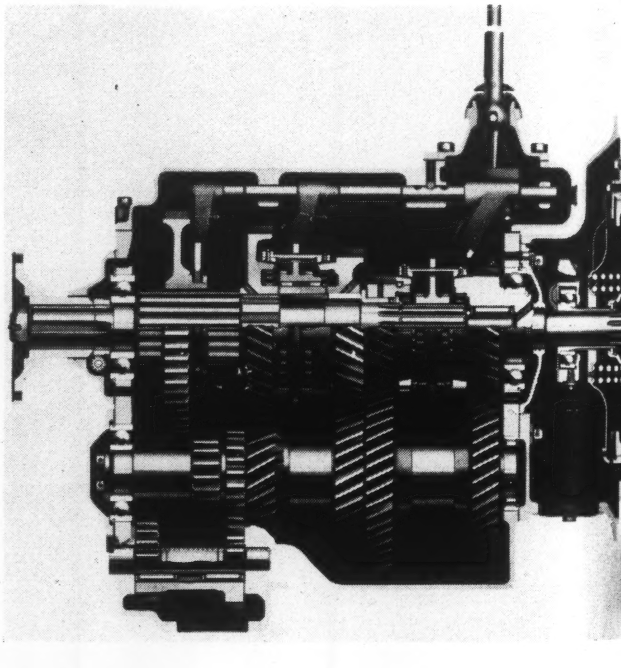
Permissible surface compressive stress on tooth flanks:

4. For continuous operation, cut gears of 130,000 to 150,000 psi ultimate tensile strength: $s_c = 90{,}000$ psi.
5. For continuous operation, carburized and ground gears as in case 2: $s_c = 135{,}000$ psi.
6. For continuous operation, carburized and ground gears as in case 3: $s_c = 160{,}000$ psi.
7. For applications where full load is applied for only short periods (automotive, for example): $s_c = 200{,}000$ psi.

Permissible "pv" factor:

8. The effect of heat generated by the sliding surfaces can generally be controlled by adequate lubricant supply as long as $K_{pv} \leqslant 3 \times 10^6$.

Fig. 20—Conventional automotive transmission, a heavy-duty synchronized 5-speed unit



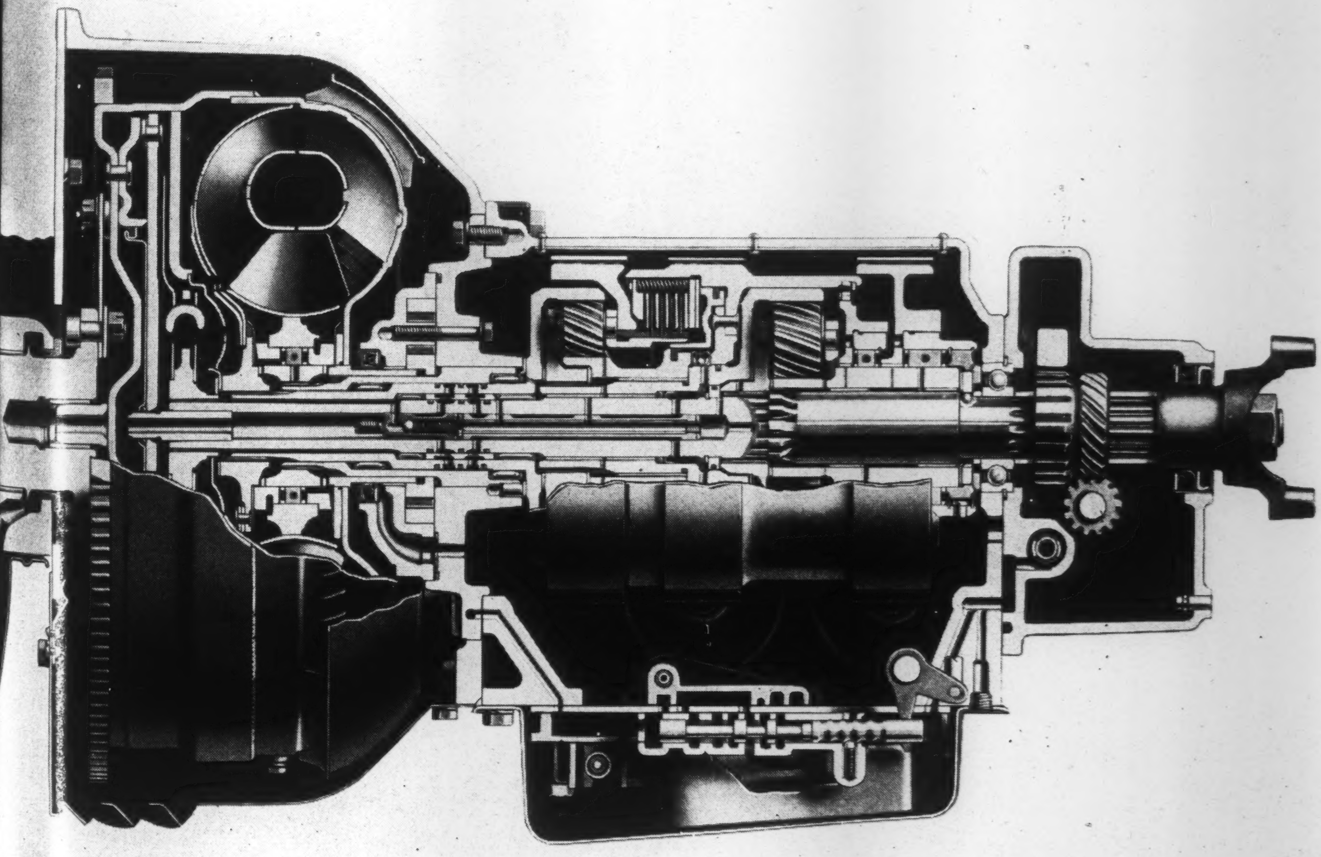
Additional Influences: It must be emphasized that, for all highly loaded gear drives, any calculation can be somewhat realistic only if the full strength of the gear tooth is actually utilized. Essentials in this respect are adequate mounting to provide correct position of the gears under load, and extreme accuracy of manufacture of the gear teeth. Metallurgical condition of the teeth must be of adequate quality. This requirement extends from material specifications to heat treating, and further into all subsequent processes, which usually have a major effect on the physical properties of the gears. Details dealing with manufacturing methods will be discussed in a later section.

Deflections under load may materially affect the operation of gears. Where weight requirements tend to reduce the rigidity of gear blanks and supporting structures, a careful check of deflections and development tests are indicated. Sometimes deflections under load may be utilized to allow the gear to compensate for small inaccuracies of mounting, and sometimes deflections of known magnitude may be anticipated and compensated in the design. Spur and helical gears of great face length will tend to twist under the driving load, but if the amount of twist is known it may be compensated by applying it to the gear teeth in the unloaded condition.

As the gear teeth deflect under load, a difference is created between the spacing of teeth in and out of mesh, *Fig.* 11. The result is that the teeth which are just entering into mesh will interfere by an amount which is a function of the deflection. The effect of this interference may be eliminated by suitable modification of the tooth form. Generally, this interference due to tooth deflection shows its effects in scoring near the tops and roots of the teeth. It is little pronounced at low speeds, but may become critical at high surface speeds and for thin-section gears, as in aircraft gas-turbine reduction drives. *Fig.* 12 shows a diagram of a gear in which this "involute modification" was obtained by suitable grinding of the tooth flanks. If this involute modification is carried too far, it will reduce the duration of tooth contact and cause noisy operation with accompanying increased tendency of surface failure.

As mentioned before, the calculated values for stresses and other unit loads must be considered reference figures, usable for comparison only with previously obtained performance records of drives of the same type. When stress data are compared, all in-

Fig. 21—Automatic automotive transmission containing torque converter and two planetary units



fluencing factors must be observed, such as the methods of calculation used, the individual design features of the gears, the arrangement of the gears with relation to the bearings and supporting structures, influence of deflections under load, metallurgical characteristics, and dimensional uniformity of the gear.

Deviations from uniform spacing of the teeth will introduce additional cyclic stresses in some of the gear teeth. A gear made to highest standards of precision will, therefore, be capable of operating at higher power than a less accurate one. Since the tooth deflection under full load is in the order of magnitude of 0.0005-inch a spacing error in that range will introduce stress increases amounting to a large fraction of the regular working stress. Gear failures on applications with conservatively calculated bending stress, particularly on high-speed drives, are frequently the result of lack of spacing uniformity. Also, any gear tooth grinding process that requires the use of a coolant will tend to leave some metallurgical irregularities at the surface because of heating of the metal in the grinding process and subsequent cooling by a stream of liquid whose uniformity can never be fully controlled.

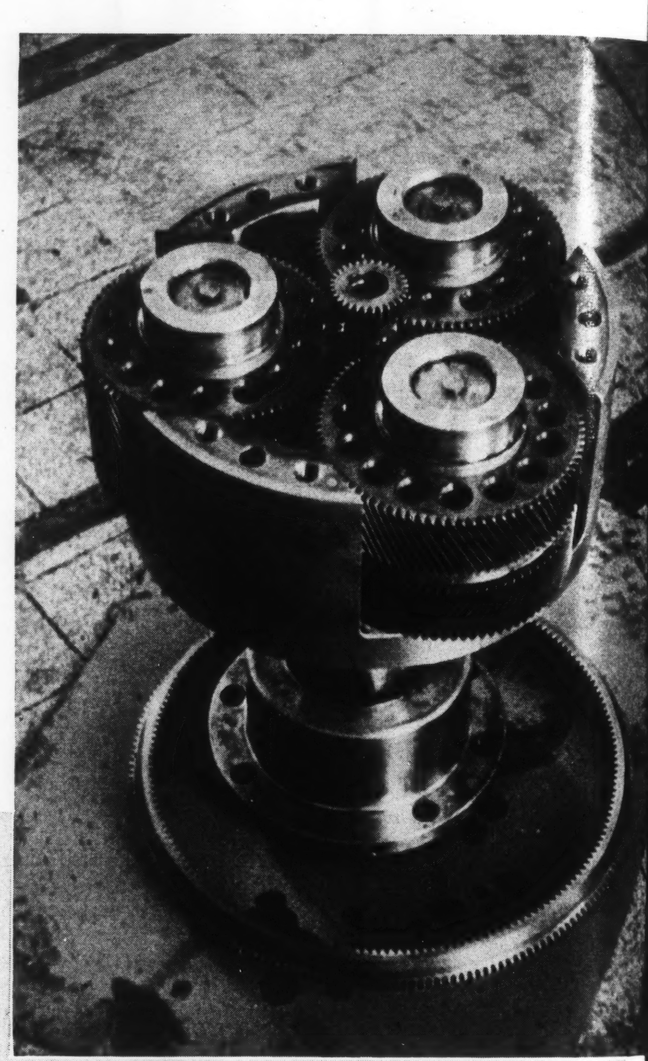


Fig. 23—High-capacity industrial planetary reduction unit

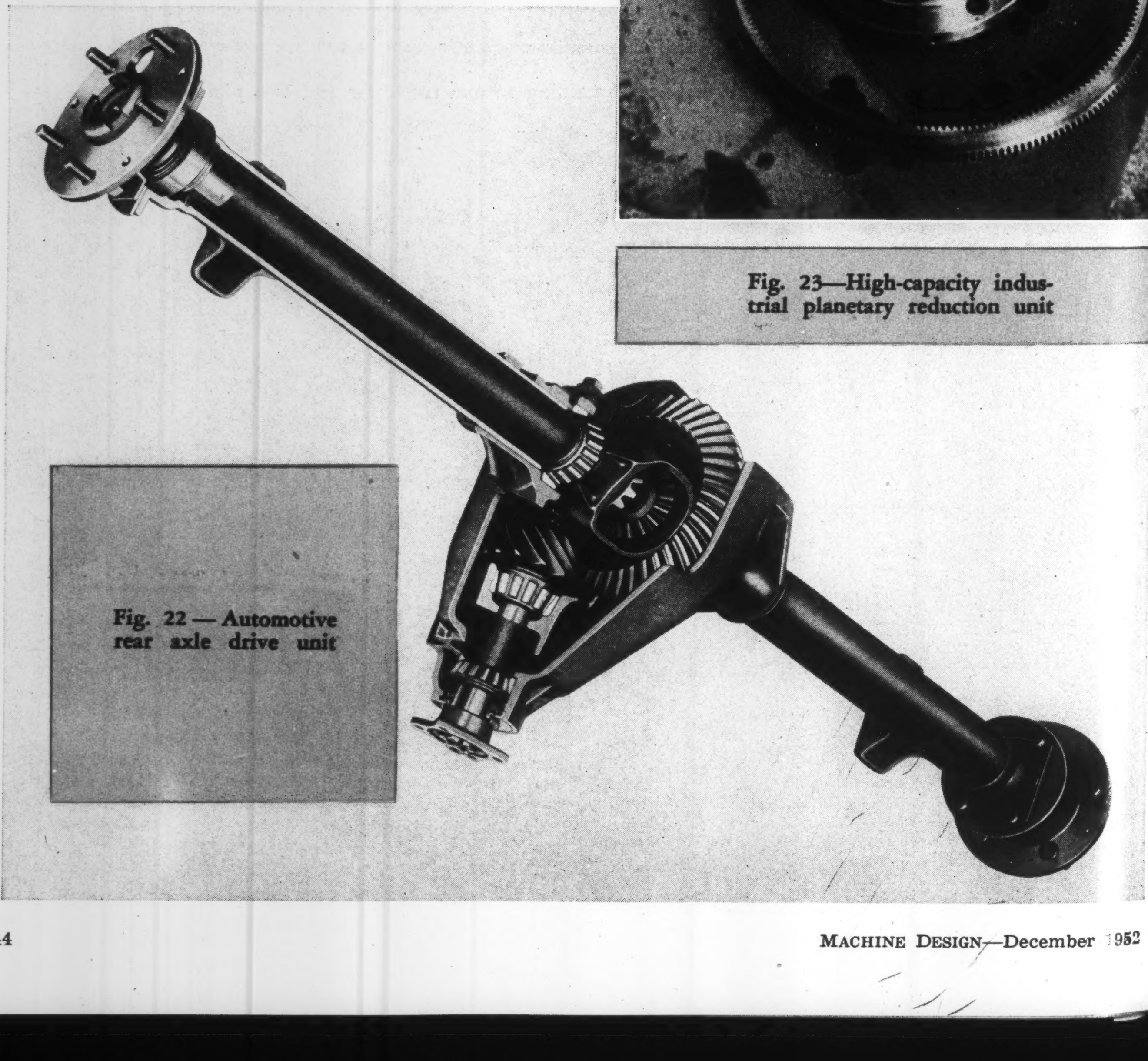
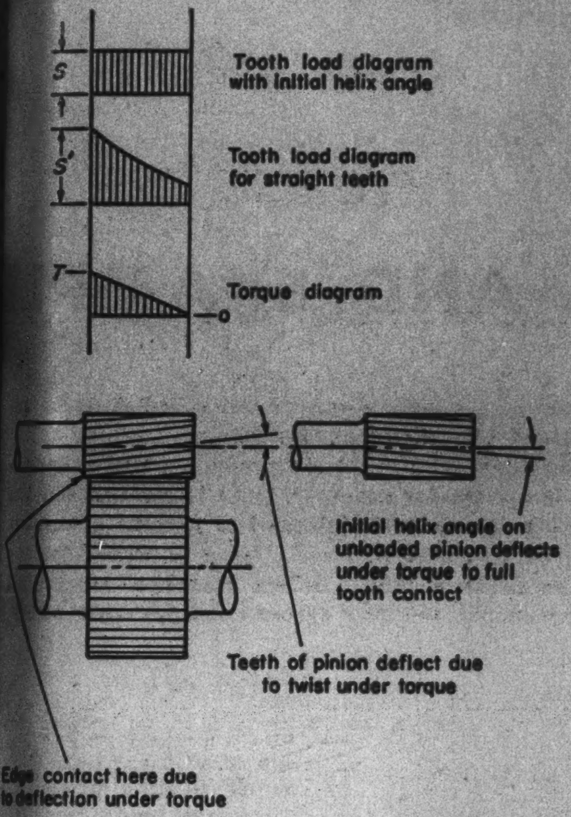


Fig. 22 — Automotive rear axle drive unit

Fig. 24—Compensation of deflection by anticipating twist under torque

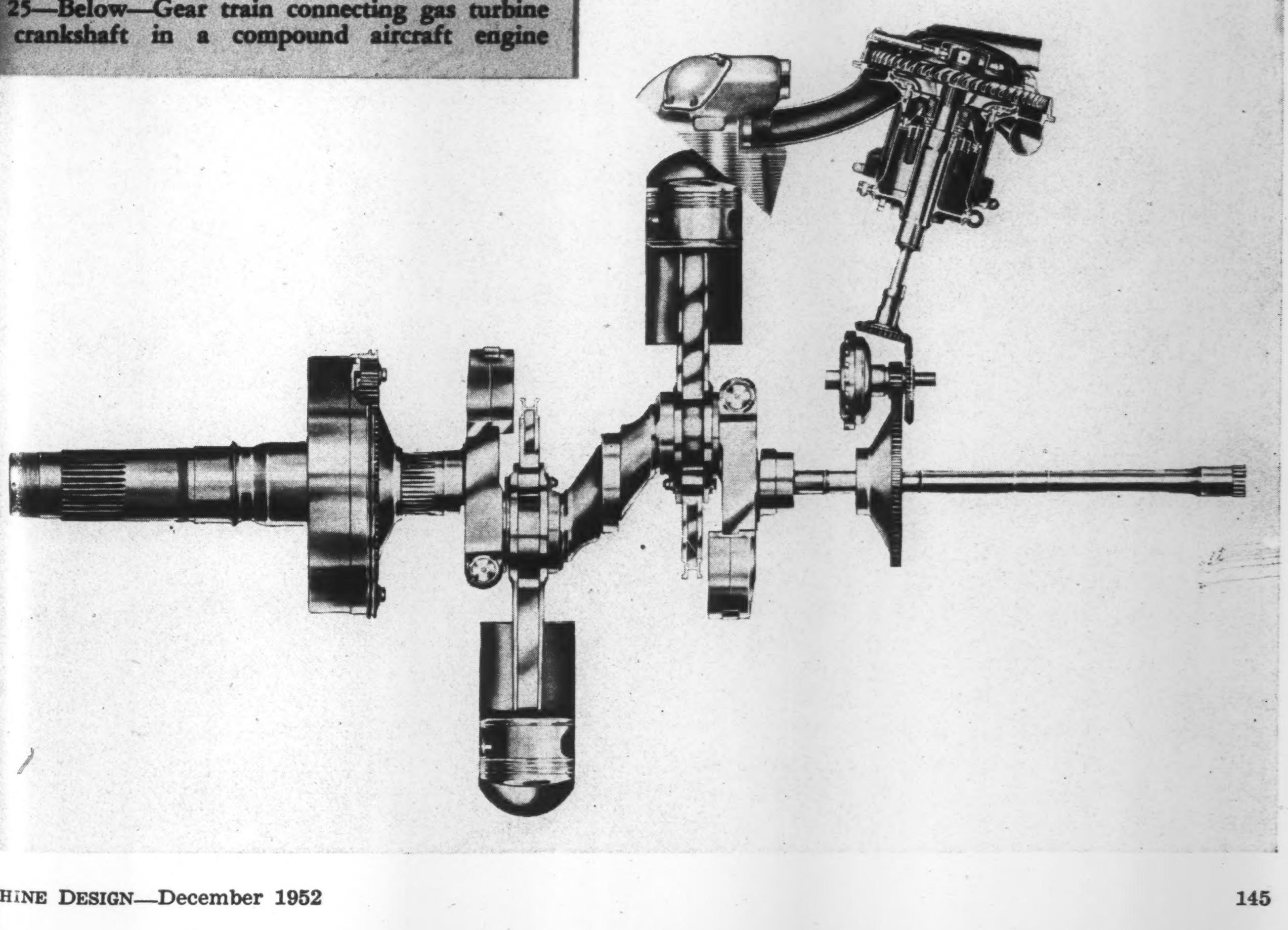

S
Tooth load diagram with initial helix angle
S'
Tooth load diagram for straight teeth
T
Torque diagram
0
Initial helix angle on unloaded pinion deflects under torque to full tooth contact
Teeth of pinion deflect due to twist under torque
Edge contact here due to deflection under torque

The limitations for the existing methods of gear stress calculations are illustrated by *Fig.* 13, which compares conditions for carburized and noncarburized gears.

Calculations give the same stress values for both cases. Strength of the noncarburized gear may closely approach the calculated figure, while the bending stress at the surface of the carburized gear is actually lower because of the inherent compressive stress in the carburized case. In addition, the ultimate tensile strength of the carburized case is about twice that of the base material. These actual stresses in a carburized gear can not be accurately calculated, and even their direct measurement by conventional methods (strain gage, Stress Coat, photoelasticity) can only indicate the difference between stress under load and without load. A clue to the inherent compressive stress in the case may be found in the increase of fatigue life due to carburization, but this method requires destructive tests of a large number of specimens.

If a carburized case on the gear teeth and highest dimensional accuracy are required the need for suitable methods of gear grinding becomes clear. A gear may be cut accurately, but in the carburizing and hardening process the accuracy is lost again. With all possible precautions, such as careful selection of material, experimentation on test pieces before actual production, controlled heating, quenching in dies

Fig. 25—Below—Gear train connecting gas turbine and crankshaft in a compound aircraft engine



under pressure, and extensive processes of reheating and deep freezing in controlled cycles, distortions may be reduced to the 0.0015-inch range. However, tests comparing the bending stress under static loads in accurately heat-treated gears versus equivalent precision-ground gears show that the unground gear is stressed up to 75 per cent or 100 per cent higher than the ground gear under the same load. The grinding process, of course, must be of a nature that will not reduce the favorable effects of carburizing. This condition is assured by limiting the grinding to the tooth flanks, as in *Fig.* 12, and by using a grinding method that will not produce elevated temperature during grinding.

High-Capacity Gearing

DESIGN DETAILS AND EXAMPLE

The design of gear transmissions is dependent on many variables. Equipment available for manufacture, engineering experience available for the design and limitations of space and weight are influential, of course. Also involved are specific requirements such as vibration resistance and noise level. And finally, adaptation to the driving and driven machinery entails an additional set of specific conditions. Often, external forces besides torque and speed must be accommodated by the transmission.

Since it is not possible to produce a generally applicable system for design of gear transmissions, the following discussion is intended to present a number of typical examples which can serve as prototypes for further developments. Before complete assemblies are considered, the gear systems for power transmis-

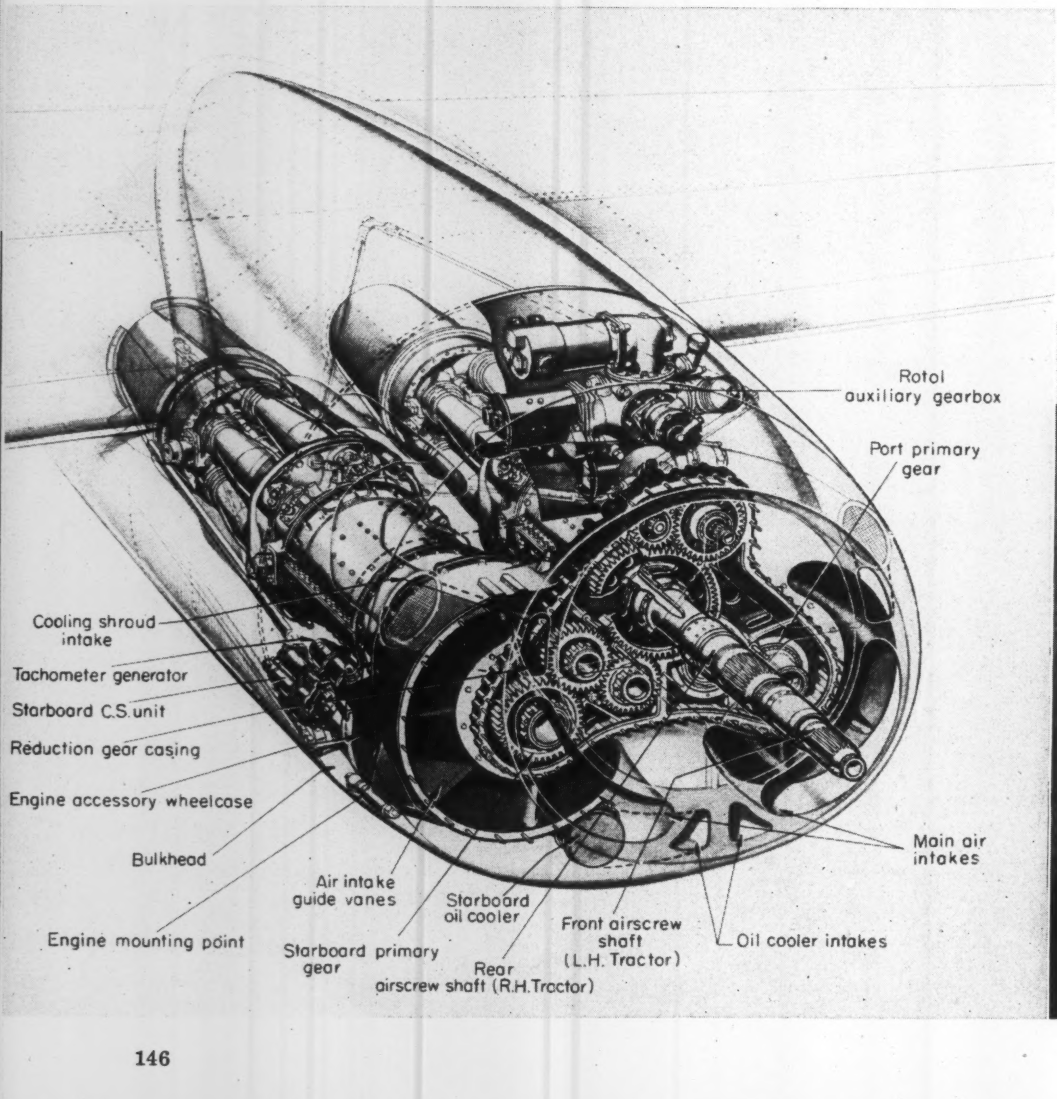
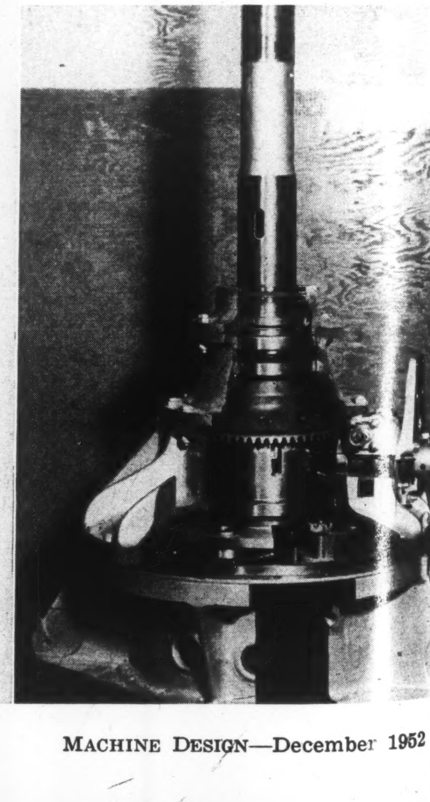

Rotol
auxiliary gearbox
Port primary
gear
Cooling shroud
intake
Tachometer generator
Starboard C.S. unit
Reduction gear casing
Engine accessory wheelcase
Bulkhead
Main air
intakes
Air intake
guide vanes
Starboard
oil cooler
Front airscrew
shaft
(L.H. Tractor)
Oil cooler intakes
Engine mounting point
Starboard primary
gear
Rear
airscrew shaft (R.H. Tractor)

Fig. 26 — Left — Gear train of twin gas turbine counter rotating propeller unit

Fig. 27 — Below — Main rotor gear box for a 200-hp single-rotor helicopter



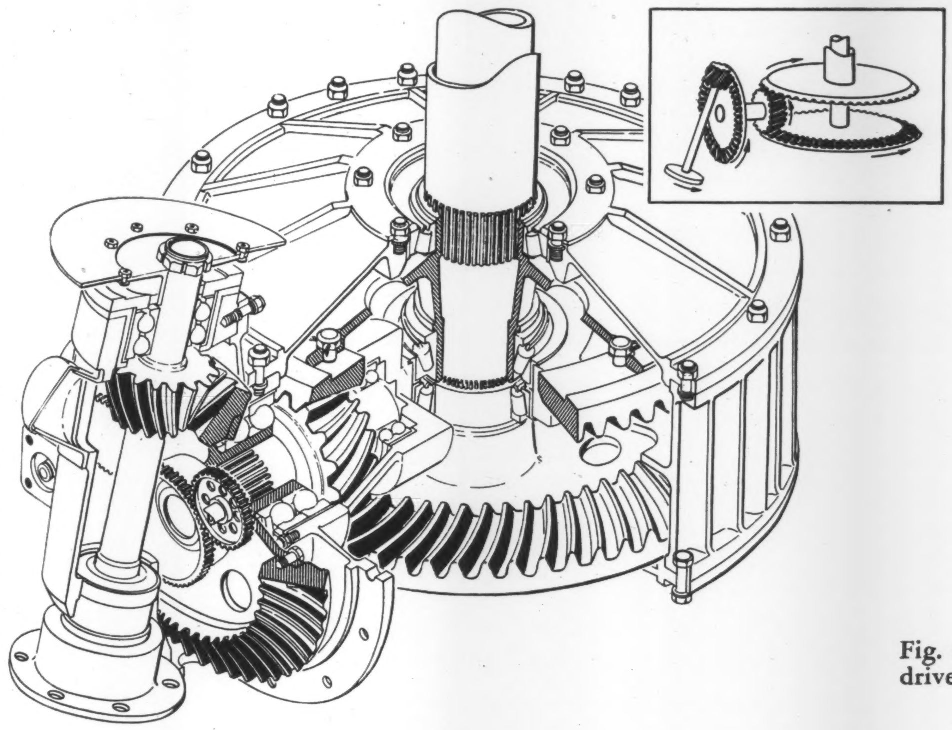
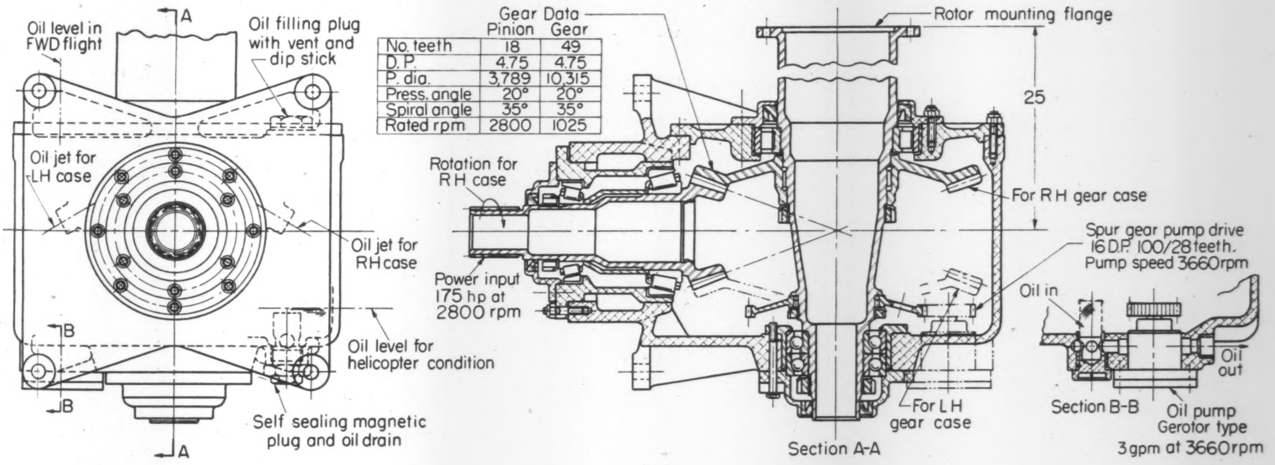


Fig. 28—Left—Gear box for a coaxial counter rotating helicopter


Oil level in FWD flight
A
Oil filling plug with vent and dip stick
Oil jet for LH case
Oil jet for RH case
B
B
Oil level for helicopter condition
Self sealing magnetic plug and oil drain
A
Rotation for R H case
Power input 175 hp at 2800 rpm
Rotor mounting flange
25
For R H gear case
Spur gear pump drive 16 D.P. 100/28 teeth. Pump speed 3660 rpm
Oil in
Oil out
For L H gear case
Section A-A
Section B-B
Oil pump Gerotor type 3 gpm at 3660 rpm

Gear Data

	Pinion	Gear
No. teeth	18	49
D.P.	4.75	4.75
P. dia.	3.789	10.315
Press. angle	20°	20°
Spiral angle	35°	35°
Rated rpm	2800	1025

Fig. 29 — Below — Bevel gear drive for a Convertiplane

sion application shall be discussed.

The involute tooth form is preferred in virtually all applications, because it provides low sliding velocities and is comparatively easy to produce. For greatest bending strength the fillet at the root of the tooth should be a maximum (full-fillet tooth). The rim under the gear teeth must be rigid enough to support the teeth as cantilever beams; its thickness should be not less than the height of the gear teeth. The ends of each tooth should be relieved slightly to reduce the load at the end planes, since less support against bending is available there than at the inner portions. For gears of small face width this end relief may exist in the form of a slight curvature extending over the full length of the tooth. Such "crowned" gears represent a compromise where deflections under load have not been sufficiently anticipated in the design. With proper end relief, the teeth will show a centralized bearing pattern when meshing without load. Under load the bearing pattern, due to elastic deformations, will extend over the major part of the length of the tooth, approaching the ends of the teeth.

Gear Types: Gears may transmit motion from shafts oriented in practically any relationship. Where the shafts are parallel, the pitch surfaces of the gears are cylindrical. If the shafts are intersecting, the gears have conical pitch surfaces. Crossed shafts are geared together by gears of various shapes, ranging from the hyperboloid bevel (Hypoid) gear to the worm gear drive in the single (cylindrical) or double enveloping (globoid) form. The meshing operation on gears with crossed shafts involves more sliding on the tooth flanks, and therefore greater friction losses than on drives with parallel or intersecting axes. For this reason, high-power installations requiring high efficiency are always designed for cylindrical or bevel gears.

Following is a summary of applicable gear types:

Parallel Shafts

1. Straight tooth cylindrical gears (spur gears)
2. Curved tooth cylindrical gears (helical gears)

Intersecting Shafts

1. Straight tooth bevel gears
   a. Radial teeth
   b. Oblique teeth (converge as tangents of a circle, instead of to the center of the cone, similar to spiral bevel gears)
2. Curved tooth bevel gears
   a. Circular curvature
   b. Cycloidal curvature
   c. Compound curvature

Crossed Shafts

1. Helical Gears with suitable helix angles
2. Hyperboloid bevel gears
3. Worm gears

With respect to curved-tooth bevel gears, incidentally, spiral bevel gears in the true geometrical sense are not in practical production.

The most common forms of bevel gears are shown in *Figs.* 14 to 16. One of the most important criteria for the selection of a gear type is its producibility and the accuracy available. Where carburized teeth are required, the question of tooth grinding becomes prominent. Until recently, only the curved-tooth bevel gear with circular curvature could be ground. The Gleason system, which uses a cupped grinding wheel with conical sides, is applicable to this type of gear. Where thrust from the spiral angle is undesirable in the design, a curved tooth bevel gear with zero spiral angle may be made (Zerol gear). Recently, the Maag gear grinding system was developed for straight and oblique bevel gears providing for the grinding of such gears by the "point-generating" system to extreme

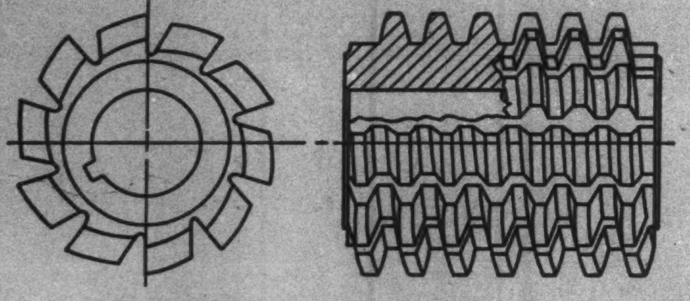


Fig. 30—Above—Gear cutting hob

Fig. 31—Below—Gear tooth generating system of Fellows

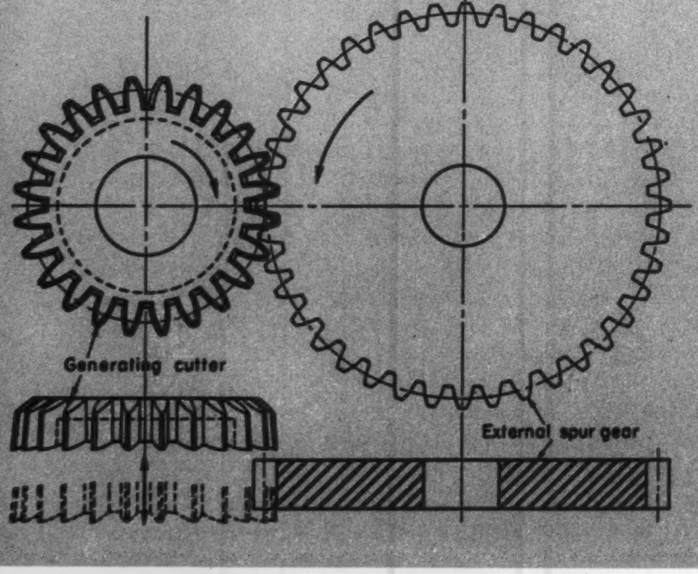
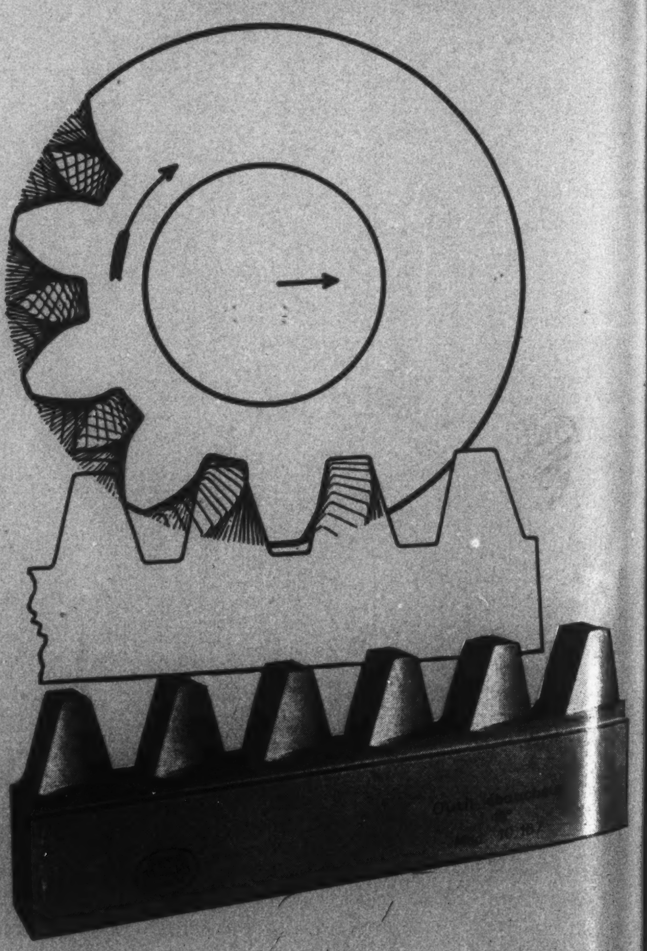


Fig. 32—Gear tooth generating system of Maag



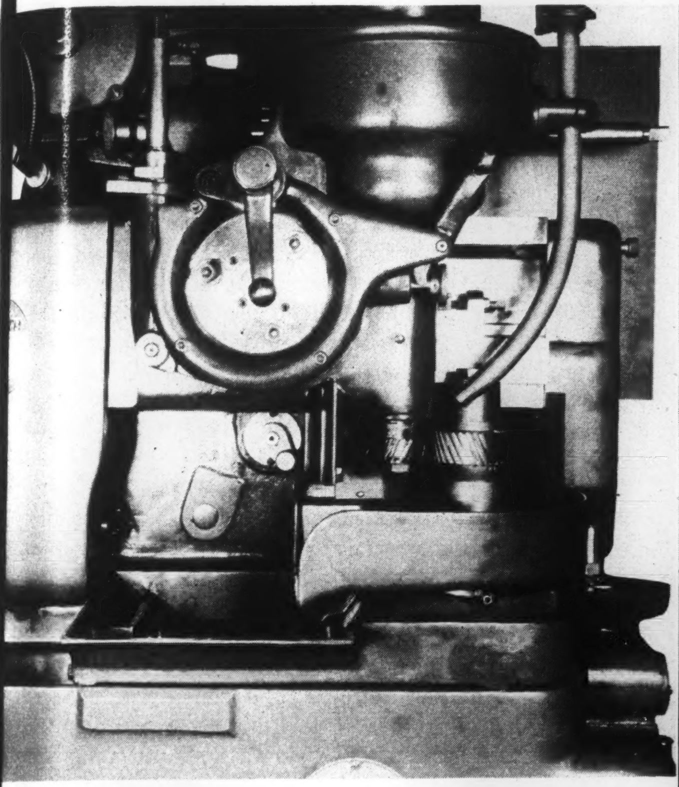


Fig. 33 — Above — Fellows gear shaping setup

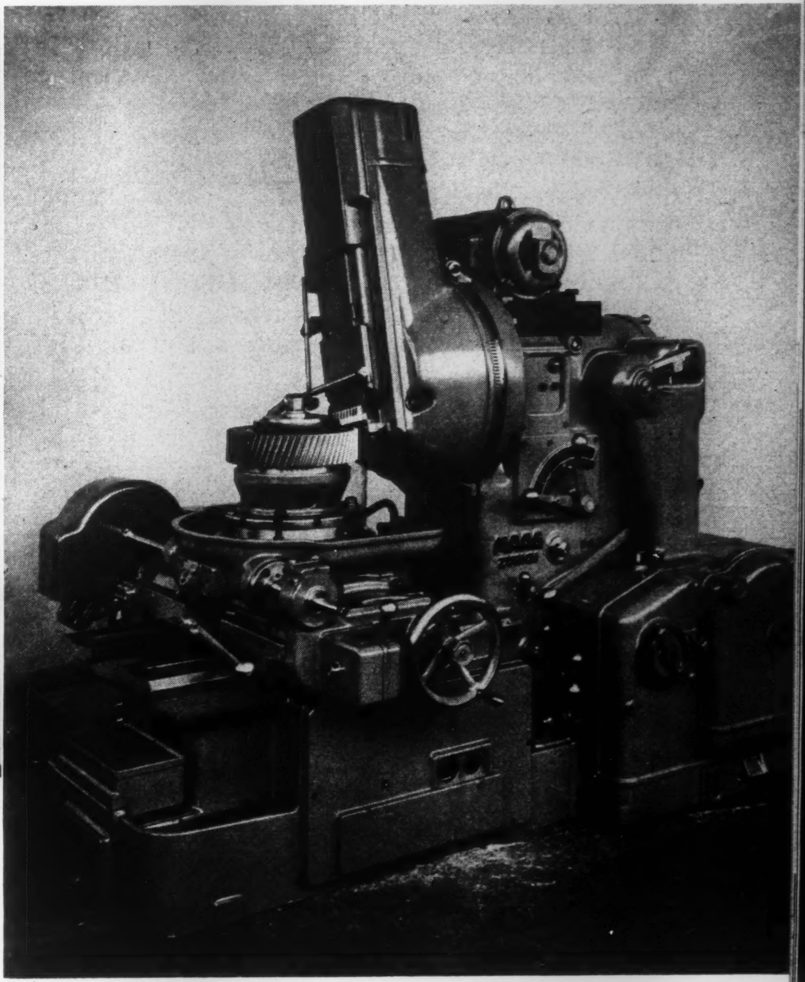


Fig. 34—Right—Maag gear shaper set up for a helical gear

degrees of accuracy. Cut bevel gears with curved teeth are made in today's industry by the circular-curvature system (Gleason), by the cycloidal-curvature system (Oerlikon), or by the compound-curvature system (Klingelnberg). These gear cutting systems will be described in the final section of this article.

A generally applicable criterion for straight versus curved or oblique-tooth gears has never been established. Analytical considerations show only small differences. It is generally recognized that curved or oblique teeth will tend to reduce the effects of inaccurate manufacture. Experience with spur gears and radial-tooth bevel gears ground to high precision indicates that such gears with tooth spacing uniformity held below the 0.0002-inch range will have a noise level below the presently available ground spiral-bevel or helical gears. A strong reason for the use of spur gears is the absence of axial thrust loads in operation, while helical gears are preferred where precision in manufacture is limited for reasons of economy and where power ratings are very high, requiring gears of great face widths. In such cases, helical gears may be made in two axially symmetrical sections forming a double-helical or herringbone gear.

Marine and Utility Applications: For many years, the herringbone gear was leading in high-power drives for marine and utility applications. It eliminates the axial thrust on the bearings, but it requires a split housing since the gears can not be assembled by axial displacement. One gear in each mesh must be axially floating so it can align itself with the other. This self-alignment is very important, since otherwise one half of the gears would take a greater load than the other. For this reason, the helix angle on double helical gears must be high (30 to 45 degrees) so that the centering force (axial component) will safely be much greater than any resistance to axial motion such as bearing friction, or friction or stiffness of adjoining couplings. *Fig.* 17 shows a 25,000 hp marine propulsion drive with 6000 rpm input speed. This unit is designed as shown in the schematic, *Fig.* 18, which gives a very compact arrangement.

Where facilities for grinding of large gears are available, the dimensions can be greatly reduced, *Fig.*

4. It then becomes possible to use the much simpler single-helical gear even for large power ratings. The helix angle may be reduced to the lowest value which still provides tooth overlap, and thus the axial thrust is small enough to be carried by shoulders on the sleeve bearings. *Fig.* 19 shows the comparison between conventional double-helical cut gears and the carburized and precision-ground single-helical gears which replaced them. This project is similar to the one shown in *Fig.* 4. These gears transmit 1350 hp at 10,080/1500 rpm; center distance is 14.2 inches; width of the old gears is 18 inches and of the new gears, 6.3 inches.

Automotive Gears: In the automotive industry, transmission gears are of as much importance as ever. *Fig.* 20 shows a conventional automotive transmission of the synchronized type. Helical gears with shallow helix angle are the rule in this type of transmission. The extensive use of hydraulic couplings and torque converters has not materially reduced the number of gears in automotive transmissions. Lower and reverse gears in such applications are usually of the planetary type. *Fig.* 21 shows an automatic transmission of this type. It uses two planetary assemblies whose rotating structures are designed to be flexible so that they will allow the gears to align themselves under operating loads.

A typical automotive rear axle unit is shown in *Fig.* 22. It uses Hypoid bevel gears for the main drive. The differential gears are of a special straight-tooth type that is particularly well-suited for large-scale production without requirements for high precision. These small bevel gears are rotating only when the two rear wheels turn at different speeds; otherwise, their load is static.

High-capacity Industrial Transmission: An interesting design for an industrial gear transmission is shown in *Fig.* 23. The designers of this transmission proceeded on the idea that an economic design may be produced by using the best available quality of manufacture. The gears are carburized and precision ground, assuring full uniformity. The planetary carrier, which holds the three double-helical pinions, is straddle-mounted in rigid bearings, and the sun gear as well as the stationary ring gear are arrranged completely free within and around the carrier, respectively. That way they align themselves fully concentrically under influence of the operating forces. The sun gear rotates fully balanced between the pitch circles of the planetary pinions without the use of any bearings. The double-helical arrangement eliminates the tilting loads which occur on single-helical planetary pinions.

Aircraft Applications: In aircraft gear drives, designed to lightest possible weight, it is rarely possible to obtain rigidity comparable to gear applications for stationary drives. The thin sections of magnesium or aluminum alloy housings and the thin walls of the hollow shafts are designed for adequate strength, but deflections are of a considerable order of magnitude. Changes in location of working parts from 0.01 to 0.02-inch between loaded and unloaded conditions are the rule. Certain ones of these deflections may be compensated for by suitable grinding of the gear teeth. For example, a long spur gear with torque input on one end may be ground with a slight helix angle opposite to the twist produced by the operating torque, *Fig.* 24. The experienced designer should always estimate the direction of the expected deflections, and make use of the flexibility of the working parts to allow them to align themselves for proper gear tooth contact under load. The gears will then operate satisfactorily as long as the most important requirements for gear quality—uniform tooth spacing and hard tooth flanks—are met.

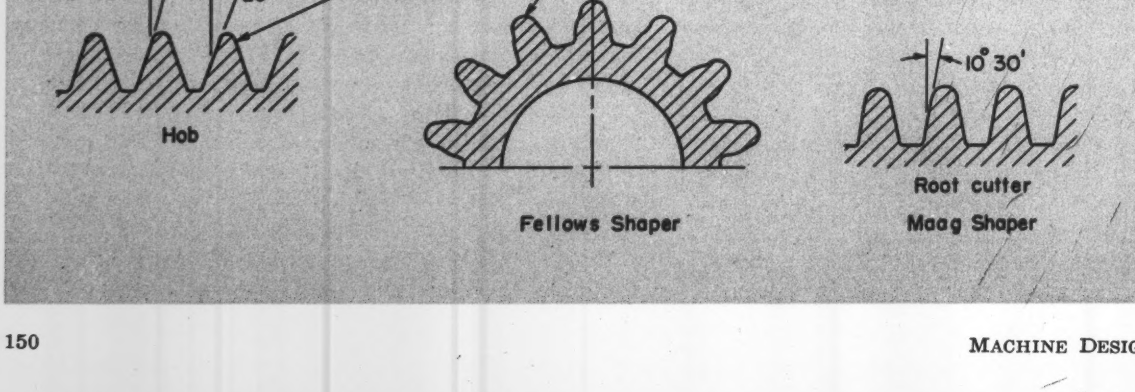


Fig. 35—Cutting of relieved root fillet

Arrangement of the gear train in the Wright Cyclone Compound engine is shown in *Fig.* 25. High speed of the exhaust gas turbines is reduced by one set of bevel and one set of spur gears to crankshaft speed.

In *Fig.* 26 are shown the propeller shaft and reduction gear train of a twin-engine turboprop installation. The power is transmitted from the 14,500-rpm turbine shafts over planetary reduction gears and free-wheeling clutches to spur gears, and from there to the propeller shafts. The engines are identical, and one drive contains an idler gear which reverses the direction of rotation so that the propellers are counterrotating. All gears in this drive are carburized and ground. The gear teeth in the planetary high-speed stages are modified involutes such as shown in *Fig.* 12 and the low-speed gears are true involutes (without modification).

Helicopter gear boxes usually contain bevel gears as well as spur gears. Preferably, spur gears are employed in planetary systems. Design of these gear boxes changes with the rotor configuration of the helicopter and the arrangement of the engine. If the engine can be arranged vertically and in line with the rotor shaft, the concentric feature of the planetary reduction-gear unit is particularly advantageous. The customary approach is to connect the sun gear to the power input, and the planetary carrier to the output shaft. The stationary ring gear is mounted in the housing. The rotor shaft which usually is supported in the gear box, and connected to the planetary carrier, must carry the weight of the aircraft, and all inertia loads occurring during flight maneuvers, and all aerodynamic forces transmitted to the rotor hub. These conditions impose additional requirements on the design criteria of the transmission, since it must accommodate these loads and eliminate the influence of excess deflections. In some cases, the rotor shaft must be hollow and extend through the gear case to permit the passage of control rods to the rotor hub.

Antifriction bearings are used throughout in helicopter transmissions of high power ratings to assure accurate location of the gears and low friction losses. Sleeve bearings would require additional oil cooling capacity which would offset any weight saving they might provide.

A cutaway view of the main rotor gear box for a 200 hp single-rotor helicopter drive is shown in *Fig.* 27. This unit is driven by a vertical engine over a centrifugal clutch with an input speed of 3100 rpm. The entire gear ratio of about 9.2 is contained in one planetary unit, with three pinions of adequately large diameter mounted on ball bearings in an aluminum alloy carrier. The tail rotor drive consists of precision ground radial tooth bevel gears, representing the first application of such gears in an American helicopter.

The gear box in *Fig.* 28 is for a helicopter with coaxial counter-rotating rotors. The requirement for two vertical shafts, turning at the same speed in opposite directions, is met by the very simple means of a horizontal bevel pinion meshing with two vertical gears. Since the engine in this configuration is arranged nearly vertical, another set of bevel gears is required; these two sets of bevel gears are used to provide the full gear ratio of 12:1. The power rating of this unit is 560 hp at 2300 rpm input. Curved-tooth bevel gears are used due to availability of suitable manufacturing equipment at the time the design was prepared. The major feature of this gear box design is simplicity and easy access to working parts. It also provides the possibility of extending control rods through the center of the rotor shafts.

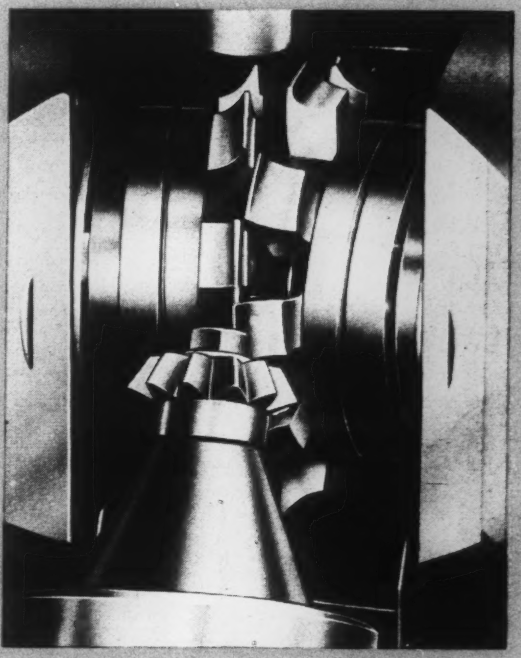


Fig. 36—Cutting of crowned bevel gear teeth with two rotating cutters

In the bevel-gear drive for a Convertiplane rotor shown in *Fig.* 29 the large bevel gear is axially positioned by a preloaded duplex angular-contact ball bearing arranged near the pinion bearings. The other bearing is axially free. Thus, the deflections of the large thin-walled housing have little effect on the mesh condition of the gears. The pinion is overhung-mounted in two tapered-roller bearings. Such an arrangement is not as rigid as a straddle mounting, but it greatly simplifies the design and is acceptable where the diameter of the gear is small enough to permit a small-diameter rigid structure around the bearings. The tapered-roller bearings are tightened axially against each other, so that small axial elongations of the housing will not produce any radial play in the bearings. This gear box transmits 175 hp at 2800/1025 rpm.

The high quality standards used on aircraft gears have initiated new developments in design and manufacture of gears and gear applications in other industries. Carburized gears, once restricted to small sizes, are used on the largest transmissions, and planetary gearing is applied on industrial and marine installations.

Quality requirements essential for such gears can be met by modern gear grinding machines which grind gears up to 140 inches in diameter to tolerances comparable to those for fine instrument gears.

High-Capacity Gearing

MANUFACTURING METHOD

Power transmitting capacity of a gear is greatly dependent on its dimensional accuracy and metallurgical properties, both being functions of the processes used in manufacture. Also, certain limitations and design requirements are connected with each process. These factors make it important for the designer to anticipate the methods that will be used in making the gears.

Since only gears of high power capacity are discussed here, only those processes which have direct influence on the quality of the gear teeth will be covered. Others shall be listed simply for completeness.

It has been mentioned previously in this article that three basic requirements must be met for a high quality gear, namely:

1. Dimensional accuracy and uniformity.
2. Adequate hardness of the surface of the tooth flanks.
3. Adequate bending strength of the tooth material.

Available Approaches: Dimensional accuracy may be obtained by suitable cutting processes or cutting and grinding processes; the physical properties must be obtained by heat treatments of various types. Any heat treatment will create dimensional distortions which will reduce or destroy the accuracy of the preceding process. In order to combine the available methods to achieve a suitable compromise, three approaches may be established:

1. Limitation of the heat treatment to a degree that will still permit cutting of the teeth to final dimensions.
2. Selection of heat-treating processes that produce only small distortions, and reduction of quality requirements to suit such processes.
3. Application of the best available heat-treating process, and finish grinding of gear teeth to desired accuracy.

Gears made according to the first approach may be used where design requirements are only moderate. Large industrial and marine gears are often designed for such processes. The blank is forged of alloy steel, rough machined, then heat treated to a Brinell hardness of 180 to 240, corresponding to ultimate tensile strength of 90,000 to 125,000 psi. Next it is finish machined and the teeth are cut. Small gears may be heat treated up to 300 bhn, and in some cases 350. The limit is established by the rigidity of the gear blank and the machine (resistance against deflection and chatter) and by the need of regrinding of the cutter. Sometimes a shaving operation is added to improve the surface finish.

If the heat treating is done after cutting, as in the second approach, and no finish grinding is used, the distortions from the heat treating must be accepted. The most desirable physical properties are obtained by carburizing, which is readily controllable with respect to depth of case and which produces a hard surface (60 Rockwell C) and a ductile core. The case is under compressive stress which increases fatigue resistance. Nitriding also produces a hard surface under compression and introduces smaller distortions due to the lower temperatures used. But it is limited to certain special alloy steels, can not produce sufficient case depths for larger gears, and is a lengthy, expensive process. Induction hardening produces a hard surface but also tensile stresses which are detrimental to fatigue resistance and bending strength of the teeth.

Shot peening, a cold working process which gives compressive stress in a thin surface layer, may be applied on soft or hard gears. It tends to produce a moderate increase of fatigue resistance.

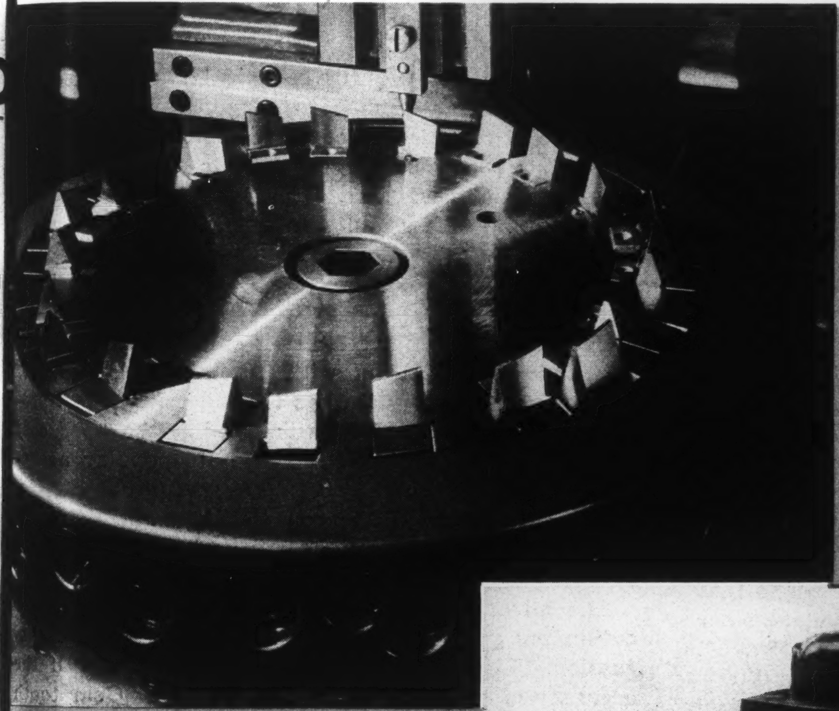
Cutting Methods: For the cutting of cylindrical gears with straight or helical teeth, three major methods are in use:

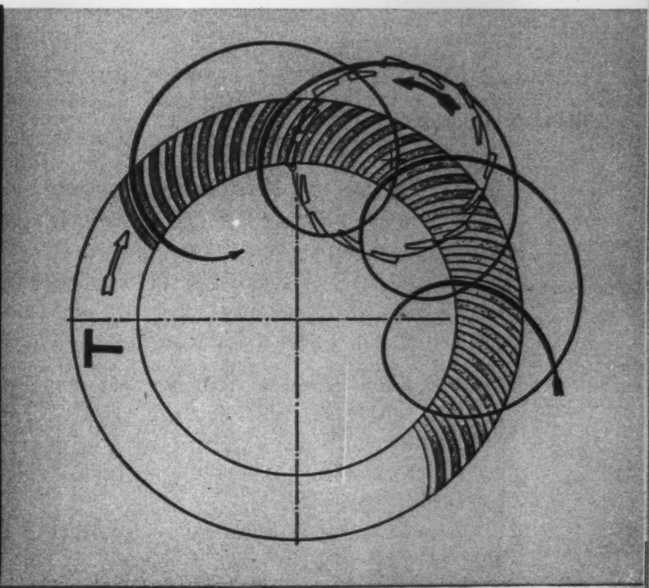
1. Hobbing with a rotating cutter geared to the blank, like a worm meshing with a worm gear, *Fig.* 30.
2. Shaping with a reciprocating circular cutter geared to the blank like another gear, *Fig.* 31.
3. Shaping with a reciprocating straight cutter, geared to the blank like a rack, *Fig.* 32.

There are other systems, some of simple nature and used only where standard equipment is not available, and others of highly specialized nature for large quantity production. Gear cutting is a highly developed science, and no attempt can be made here to fully describe all methods. Only the characteristics of importance to the designer shall be mentioned.

Hobbing is the preferred method for medium to high production, but it has dimensional limitations and will not, in general, produce a surface finish and accuracy equal to a shaped gear. Diameter of the hob imposes clearance requirements. The cutting action of the hob teeth produces a fine ripple pattern on the surfaces. Rigidity of the structure supporting the hob is limited by space conditions, and the large forces occurring in the cutting process may lead to deflections which will affect the accuracy of the finished gear.

Shaving, as a final finishing process, is sometimes used to improve the quality of unhardened gears. It consists of removal of a thin layer of material from the surface of the teeth by a tool which continuously scrapes and burnishes. The cutter meshes with the gear but is not positively geared to it; working pressure is obtained by a friction brake on the cutter





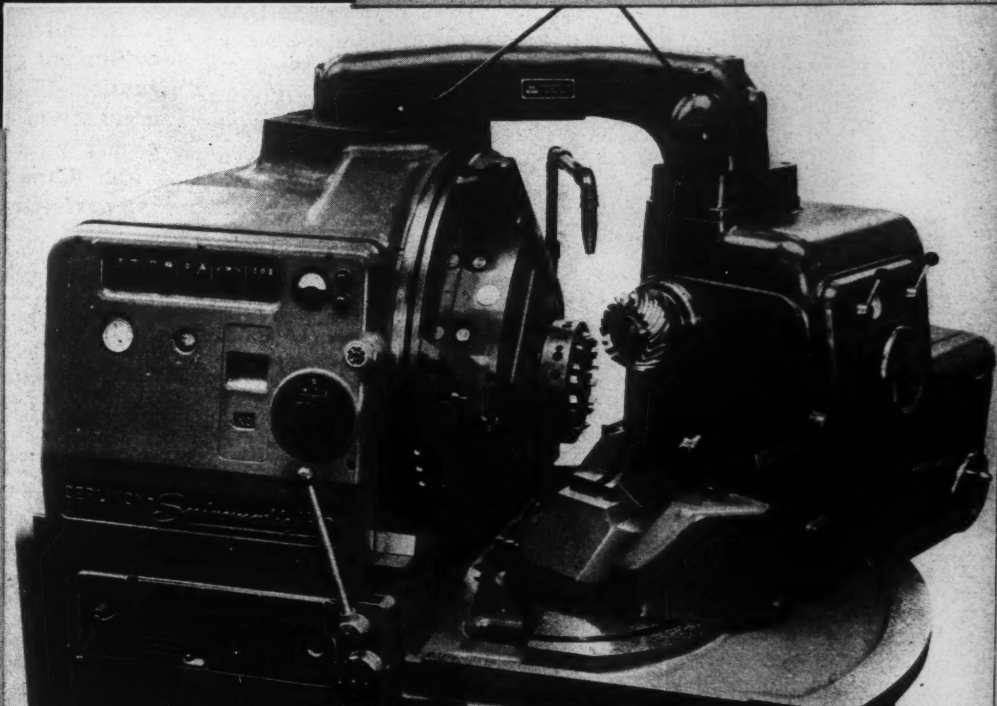


Fig. 37—Above—Cutter head for spiral bevel gear cutting by the Oerlikon system

Fig. 38—Above, right—Oerlikon system of continuous spiral bevel gear cutting

Fig. 39 — Right — Oerlikon continuous spiral bevel gear generator

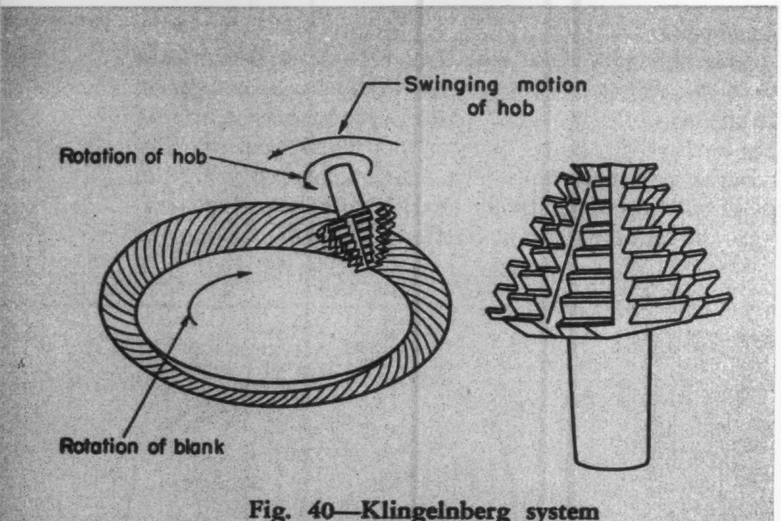


Fig. 40—Klingelnberg system of spiral bevel gear cutting

shaft. This process will permit gear finishing to smooth surfaces and correct tooth form, but since the cutter motion is guided by the gear, it will tend to reproduce any errors in uniformity left from the preceding process.

Gear shaping is done by reciprocating tools operating in the longitudinal direction of the teeth. The Fellows system uses circular cutters of a shape that will generate the correct tooth form in the blank since the cutter and blank are geared together, *Fig.* 31. This process is extensively used for external and internal spur gears. It also may be adapted to helical gears by using special guide sleeves which impart a rotating motion to the cutter as it reciprocates. *Fig.* 33 shows a working setup on a Fellows gear shaper.

The gear cutting system of Maag uses a rack-shaped cutter with straight-sided teeth which generate an accurate involute form on the gear, *Fig.* 32. These cutters are easily produced on conventional equipment. The cutter slide of the Maag gear cutter may be tilted to any angle, permitting the cutting of any desired helix angle, *Fig.* 34. This machine works to close tolerances, and the quality of finish is inherently favored by the close support of the cutting tool on the sliding ways in all positions of the stroke. This machine may also be set to cut on both forward and return stroke for greater productivity.

A relieved root, such as shown in *Fig.* 12, is made on hobbing machines and Fellows shapers with special "protruberance" cutters. On Maag shapers cutting on both up and down stroke, two simple cutters may be used, one for the relieved root and one for the tooth flanks, as shown in *Fig.* 35.

Bevel gears with straight teeth, either radial or oblique, are shaped by reciprocating tools. The involute form is generated by rolling the blank on a cone relative to the tool. The tool has a single straight contour. Two tool slides are used, operating alternately with reciprocating motion, cutting on the stroke toward the apex. Many types of machines, both domestic and foreign, are based on this principle. Another method uses two rotating cutters and produces "crowned" teeth, that is, teeth with slightly curved flanks, *Fig.* 36.

Bevel gears with curved teeth, commonly called spiral bevel gears, are manufactured by several systems of which only three are of major practical importance. One is the Gleason system, which produces a tooth whose curvature is basically circular. The teeth are cut by a rotating tool which is indexed from space to space. If the spiral angle is set to zero, the gear is similar to a radial straight-tooth gear except for the curvature of the teeth.

Another spiral bevel gear system is used on the Oerlikon machines. Cutter head, *Fig.* 37, and blank are geared together and rotate continuously without indexing, *Fig.* 38. The resulting saving of indexing time greatly increases the efficiency of this machine, *Fig.* 39.

The Klingelnberg system cuts spiral bevel gears in a continuous operation with special hobs, *Fig.* 40. This gear cutting system has the inherently high productivity of the hobbing principle, but the high cost of the cutting tools has retarded its popular acceptance.

All three systems—Gleason, Oerlikon, and Klingelnberg—can produce bevel gears for intersecting axes as well as hyperboloid gears for crossed axes.

The advantage in power transmitting capacity of carburized gears has been emphasized in previous discussion. This advantage can be realized only if the accuracy of the gear teeth is maintained. Gear tooth accuracy is a summation of many characteristics. Pitch diameter must be concentric with the mounting surfaces of the gear. The form of the tooth flanks

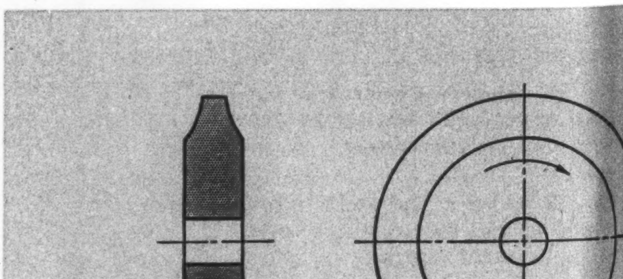


Fig. 41—Formed-wheel gear tooth grinding

must be a true involute, or a modified involute as specified by design criteria. Teeth must have the correct helix angle which must be uniform on all teeth. Spacing from tooth to tooth must be uniform all around the gear.

Eccentricity of pitch diameter will produce cyclical variations in speed with resulting inertia loads. Incorrect helix angles will lead to concentration of loads near the ends of the teeth with accompanying stress increase. Spacing errors will result in additional loads on the gear teeth, due both to inertia loads and reduced contact ratio.

Combinations of all these errors are present on every gear to some extent. During the cutting process, they are produced by deflections of blank, cutter, and their supports under the cutting pressures which become higher with harder blank materials. Subsequent hardening will always produce some distortions. Many methods have been devised for reducing the distortions in hardening: controlled heating, cooling and deep freezing, and quenching in straightening fixtures under pressure. Even localized shot peening has been used to change the curvature of thin ring gears that had become oval. In some individual cases, success was claimed, but the accuracy data obtained by these methods were always based on measuring methods which disclose only one type of error while disregarding others.

Grinding Methods: Although hardening to lowest distortion is definitely a desirable process, the only safe way of obtaining the necessary accuracy is grinding to final dimensions after carburizing. The grinding process, however, must be carried out in a manner that will not reduce the metallurgical qualities of the teeth. Since the carburized surface is under a compressive stress which increases fatigue resistance, it is best not to remove the outer layer in the portion of highest bending stress, namely, in the root fillet. For this reason, the full-fillet tooth with relieved root is preferred for highly loaded gears operating at high speeds. The flanks, which perform the meshing operation, must be ground. If shot peening is desired, it should be done before the grinding so that it will give its effect on the roots. Then the undesirable roughness resulting from the shot peening on the flanks will be removed in grinding.

Gear grinding systems may be divided according to the method by which the involute form of the teeth is produced. Mechanically simplest is form grinding by a wheel which is dressed to the proper profile and passed through the spaces, *Fig.* 41. Wear of the grinding wheel is an important factor in this system, since it affects shape and size of the gear teeth. Consequently, there is a tendency to use hard grinding wheels which wear only a little in the grinding process. The wheel contacts the gear teeth over a wide area, which results in high friction and heat generation. This heat must be dissipated by a stream of coolant directed at the working area. Use of hard grinding wheels further increases the friction and heat at the gear teeth, since the grit of the wheel be-

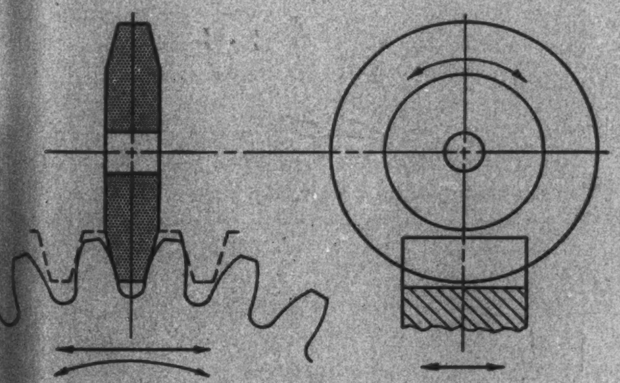


Fig. 42—Above—Gear tooth generating grinding with straight-contour wheel

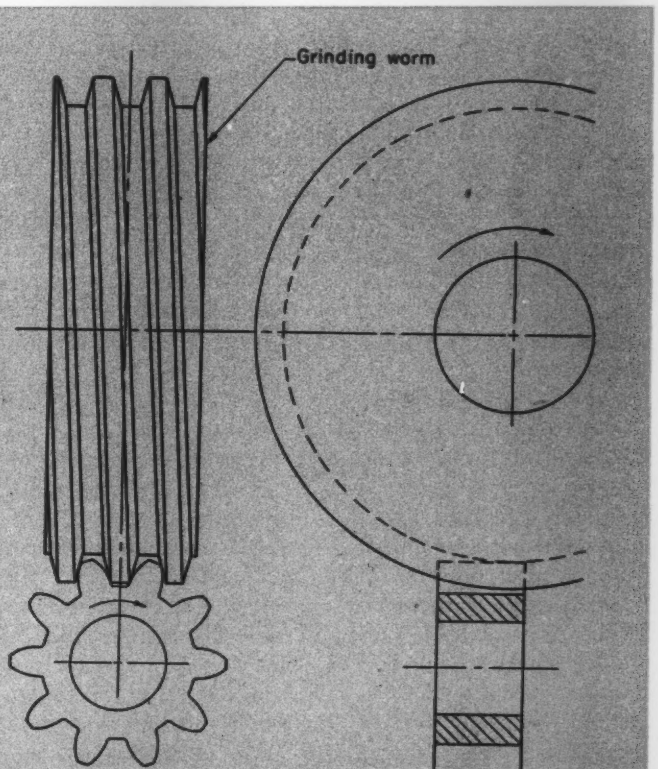


Fig. 43—Reishauer gear grinding system

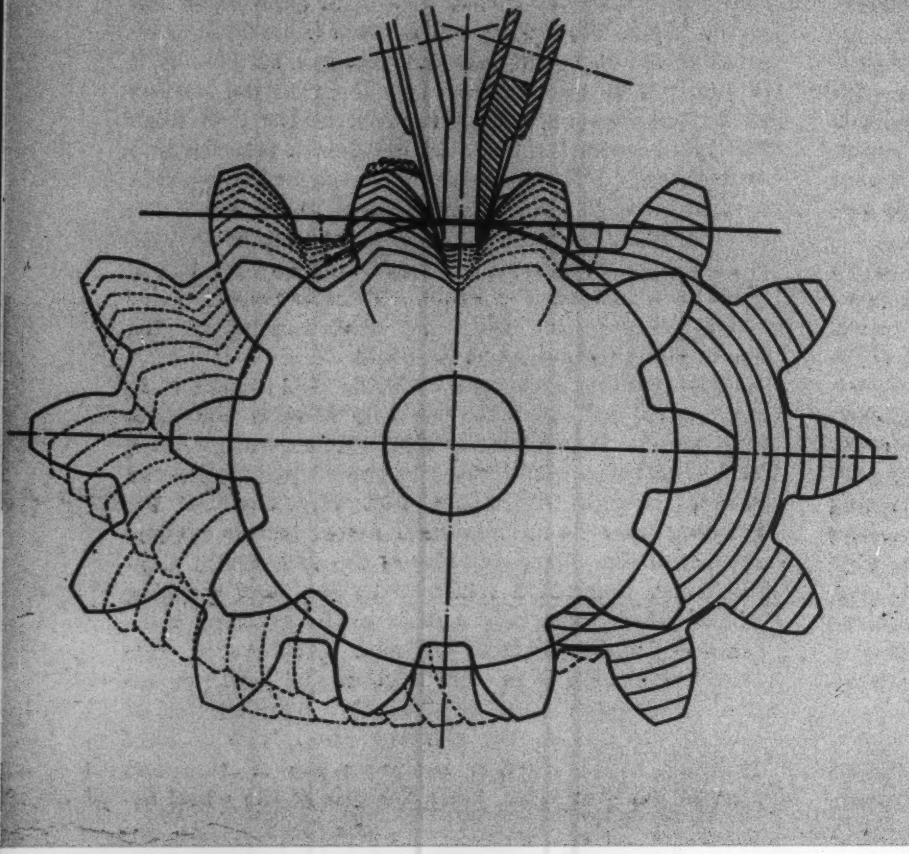


Fig. 44—Left—Gear tooth generating grinding process of Maag

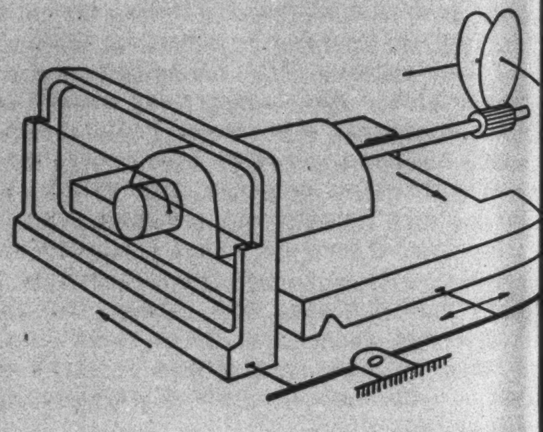


Fig. 45—Below—Involute generating linkage on the Maag gear grinder

comes dulled in the grinding process and the hard bond holds the dulled grit in place. The result may be overheating with accompanying reduction of surface hardness, or cracks even may be produced in the carburized case. On gears with large numbers of teeth, the wear of the grinding wheel may exceed the acceptable tolerance for uniformity. The formed wheel process is, therefore, not well suited for gears with many teeth (about 75 and up) nor for gears intended for highest quality requirements. Its major application is in grinding splines or gears of special noninvolute form.

Another process used for gear grinding generates the involute by a wheel with straight sides, *Fig.* 42. The side of the grinding wheel represents a tooth of the basic rack meshing with the gear to be ground. Gear and grinding-wheel slide are linked together over a master gear and master rack. In this process, the contact area between grinding wheel and gear tooth is smaller than in formed-wheel grinding, but the heat generation is still sufficient to require the use of liquid coolant. Danger of local grinding burns is a factor to be considered. Wear of the grinding wheel changes size and form of the gear teeth, so that hard grinding wheels are required also for this process. Dressing of the wheel is reduced to correcting the straight line contour, after which the correct tooth size must be readjusted.

The Reishauer method of gear grinding uses a wheel which is grooved in a helix and has a profile like the basic rack, *Fig.* 43. The wheel thus meshes with the gear as a worm meshes with a worm gear, or as a hob with a gear blank in cutting. Due to the large number of surfaces in operation, this process is very rapid after the correct setup is made and as long as no redressing of the wheel is needed. The quality of the grinding job, dimensionally and metallurgically, is comparable or better than on the straight wheel process.

Sufficient cooling by a liquid is necessary, and grinding burns are a possibility. Wear of the grinding worm must be minimized by use of hard bonds which again result in increased friction and heat at the surfaces.

Synchronization between gear and grinding worm rotation is done on the Reishauer machine by electric synchronous motors which are an unusual design element for this type of machinery. The advantage is the elimination of some mechanical gear trains and shafting although accurately regulated line voltage is required.

The danger of overheating from friction between grinding wheel and gear has caused much concern where gears for highest power capacity are required.

Fig. 46—Right—Maag gear grinder for small and medium size gears

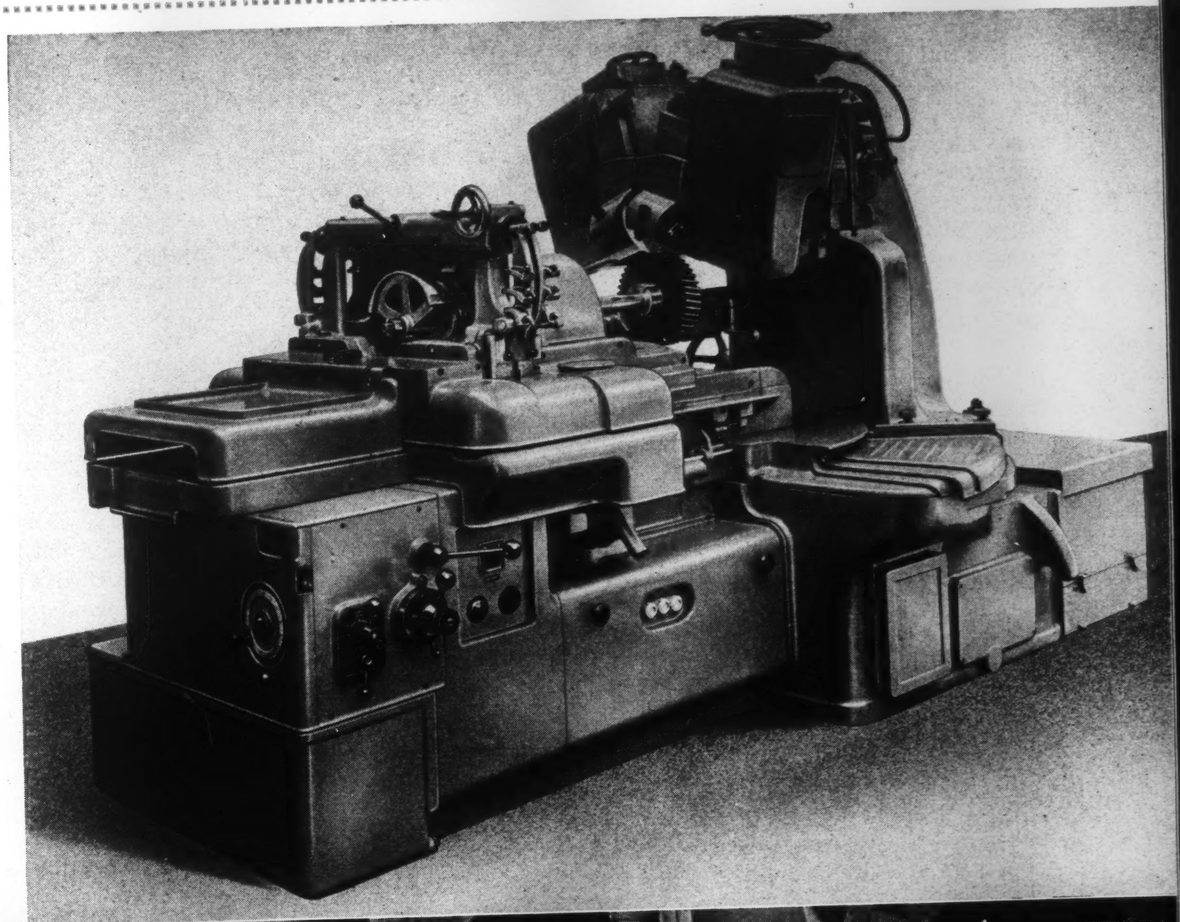
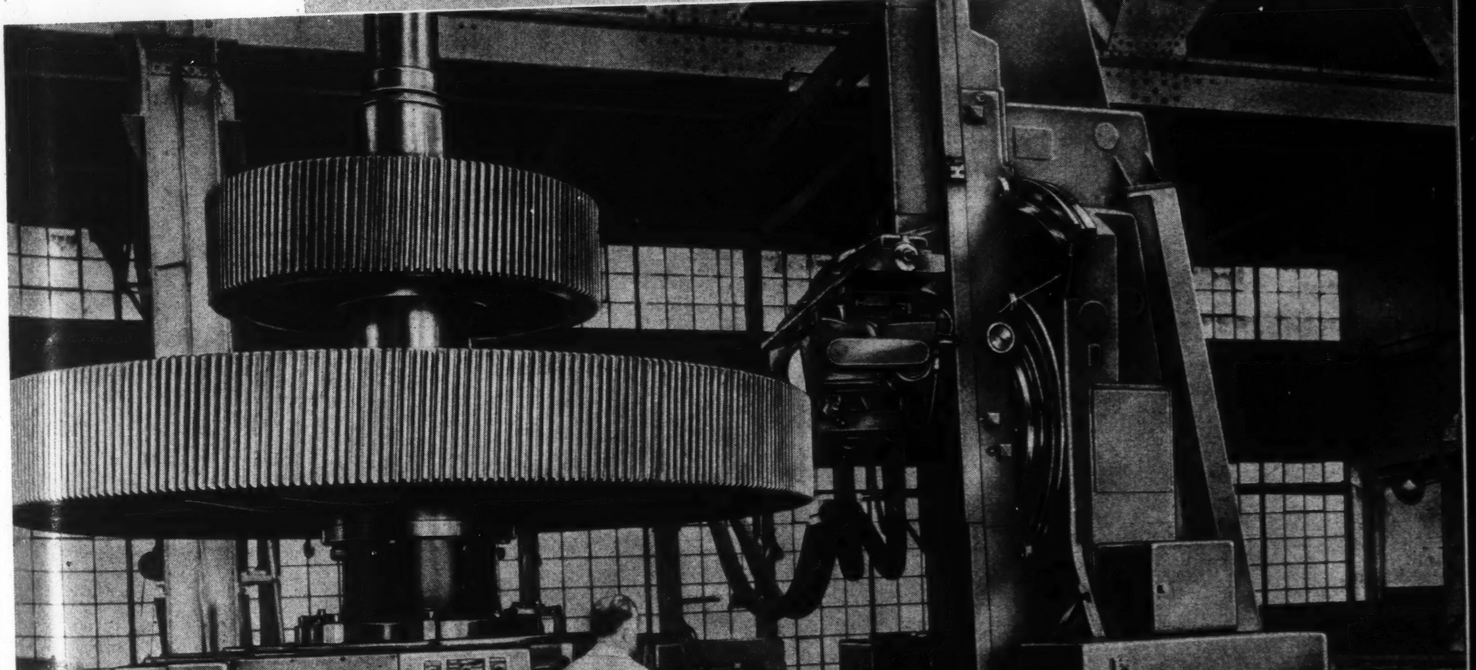


Fig. 47 — Below — Maag gear tooth grinding machine for pitch diameters up to 142 inches



The Nital etch test, an application of a mixture of nitric acid and alcohol, reveals spots where the surface has been overheated, but there is no way of detecting any subsurface stresses that may have been caused by the heating and subsequent cooling, or by irregularities in the coolant flow. For this reason, the allowable stresses in gears ground by one of the processes just discussed must be established with a greater safety factor than for a process that avoids such heat generation within the grinding process.

The "point-generating" system by Maag accomplishes such cold grinding by two basic features inherent in the process, namely: (1) the grinding wheel contacts the gear tooth in only two theoretical points, using only the thin edge of the wheel for grinding, and (2) the wheel is made with soft bond so that it will wear continuously and bring new sharp grit to the surface. The wear of the wheel is compensated during the grinding process by automatic adjustment.

Principle of the Maag generating process is shown in *Fig.* 44. The wheels are saucer-shaped, one wheel always contacting one tooth only with the convex edge of the outer circumference. The gear is linked to the grinding wheels by a linkage shown schematically in *Fig.* 45. The wheels are rotating in place, and all generating and longitudinal feed motions are performed by the gear.

Due to the small contact area between grinding wheel and gear, friction and generated heat are reduced to a value that permits natural heat dissipation. The gear remains cool during grinding, and the grinding dust is carried off by exhaust fans. Thus, bearings and slides of the machine remain free of abrasive sludge, unlike machines using liquid coolants. Consequently, frictional resistance of the moving parts is kept low and uniform and errors due to uneven deflections are eliminated.

During the grinding process, the edge of the grinding wheel is automatically checked in short intervals, about every two seconds, by a flat diamond feeler. As soon as the wear of the wheel approaches 0.001-mm (0.00004-inch), an adjusting mechanism resets the wheel until the grinding edge is in its original

Fig. 48—Maag bevel gear grinder

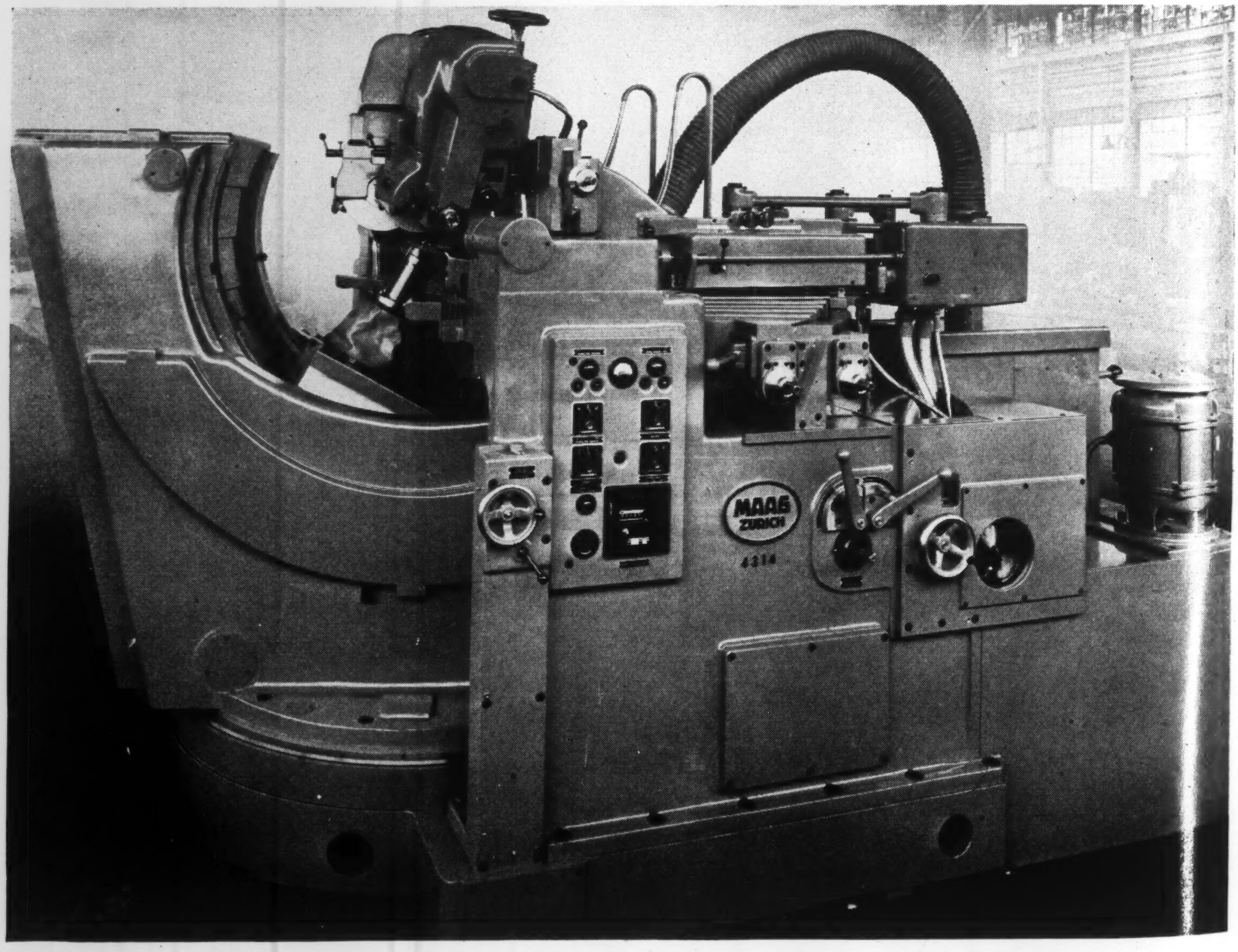
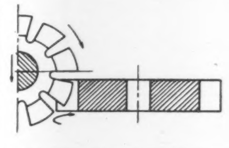
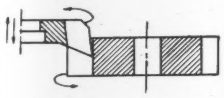
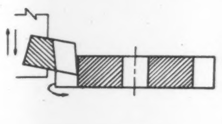
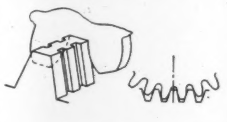
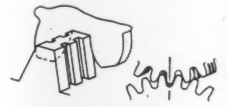
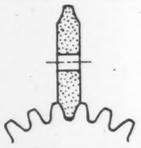
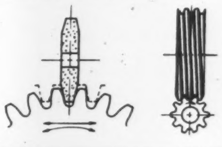
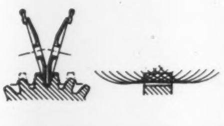
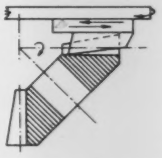
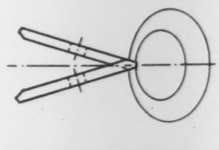
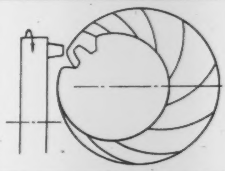
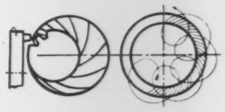
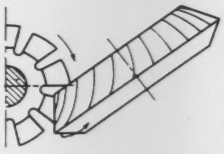
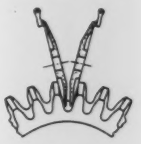
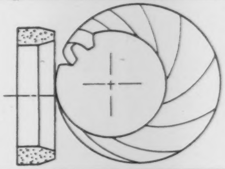


TABLE 2— GEAR MANUFACTURING PROCESSES

SPUR AND HELICAL GEARS	
CUTTING	
HOBBING Industrial, automotive, general-purpose gears	
SHAPING, CIRCULAR CUTTER (Fellow) Industrial, automotive, general-purpose gears	
SHAPING, RACK CUTTER (Maag) Industrial, automotive, general-purpose gears	
SHAVING	
RACK SHAVING Improved industrial and automotive gears; soft, or carburized after shaving. Instrument gears	
CROSSED-AXIS WHEEL SHAVING Same applications as rack shaving	
GRINDING	
CONTOUR Medium to high-capacity gears	
LINE GENERATING Medium to high-capacity gears	
POINT GENERATING (Maag) High-capacity and master gears	

BEVEL GEARS	
CUTTING STRAIGHT TEETH	
SHAPING General-purpose gears	
MILLING General-purpose gears	
CUTTING CURVED TEETH	
CIRCULAR (Gleason) General-purpose and automotive gears	
CYCLOIDAL (Oerlikon) General-purpose and automotive gears	
COMPOUND (Palloid, Klingelnberg) General-purpose and automotive gears	
GRINDING STRAIGHT TEETH	
MAAG High-capacity and high-speed gears	
GRINDING CURVED TEETH	
GLEASON High-capacity and high-speed gears	

METALLURGICAL IMPROVEMENTS

CARBURIZE
Automotive gears (unground), high-capacity gears (ground)

NITRIDE
Special gears where carburizing is not possible

SURFACE HARDEN (Flame)
Large gears subject to abrasion

SURFACE HARDEN (Induction)
Medium-size gears subject to abrasion

SHOT PEEN (Surface compression)
High-capacity gears (special cases)

position. Size and form of the teeth are thus independent of grinding wheel wear, and the Maag system may be used for any number of teeth without losing uniformity. This makes it applicable to gears of any size, including large marine gears. *Fig.* 46 shows a Maag gear grinder for small and medium size gears. This machine, originally used mainly for master gears and special high precision work, is now finding increasing use in the aircraft gear industry for turboprop reduction and jet engine accessory drives, and in helicopter transmissions. The machine shown in *Fig.* 47, probably the largest gear grinder in the world, was designed and built by Maag for the U. S. Navy for naval vessel propulsion reduction gears.

Modified involute forms are ground on formed-wheel machines by dressing the grinding wheel to a suitable shape from templates adapted to the regular wheel-dressing unit. Machines using flat grinding wheels and Reishauer machines may be adapted to modified involutes by changing the otherwise straight contour of the wheel profile to a curved profile which will generate the desired final tooth form. This technique, however, essentially complicates the wheel dressing process. The Maag gear grinders are equipped with an attachment which imparts an additonal rolling motion to the gear as the involute is generated. The amount of modification is adjustable to the desired value.

Grinding of bevel gears has so far been limited to the Maag system for radial and oblique teeth, and to the Gleason system for curved teeth. The Maag point-generating system is applied to bevel gears through an arrangement that imparts a rolling motion to the gear around its axis and a swivelling motion of the grinding wheel carriers around the apex. The grinding wheels are fed along the teeth alternating, so that each wheel clears the narrow space near the center as the other one approaches. *Fig.* 48 shows the Maag bevel gear grinder. Grinding is performed dry, and dimensional accuracy and metallurgical quality of Maag ground bevel gears are equivalent to cylindrical gears finished by this process.

Curved-tooth bevel gears are ground by the Gleason system, using a cupped grinding wheel with inclined straight sides. The wheel represents the geometrical shape of the envelope surface of a Gleason type cutter, generating the involute from the straight contour of the wheel. Grinding is done with coolant. Automatic dressing of the wheel to the straight-sided form is done between grinding cycles.

A summary of the various gear manufacturing processes is presented in TABLE 2.

Summary: Demand for higher capacity is gradually pervading almost all fields of application of gear drives. That need is being matched by progress in design techniques, metallurgical standards, and manufacturing facilities. These gains can be converted to direct benefit in specific applications by thorough-going design analyses that conform to no static or conventional concepts. Each gear set design is a challenge to apply the best of available common knowledge combined with the alert recognition of the possible "special" variations that are adaptable to that design and its application alone. Only through such thinking has the art advanced and will it continue to gain.

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United Helicopters Inc.	***Fig.* 27**
Westinghouse Electric Corp.	***Fig.* 2**

GEAR DESIGN

Nomograms simplify solution of preliminary design equations for hardened and ground gears

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LAYING out a pair of gears or a gear train may often be repeated several or many times in the course of design, according to the limitations imposed by function, space, weight, or a possible multiude of related conditions. In another article in this ssue (Page 129), simplified design equations are preented to aid the rapid determination of the proporions of high-capacity gears within an accuracy range sually adequate for exploratory layouts. In this ata Sheet, nomographic solutions of the short-cut quations are given.

Charts and Equations: The three accompanying harts are applicable to the design of gears which ave carburized and ground teeth. *Fig.* 1 gives pitch iameters of spur and helical pinions and *Fig.* 2 gives itch diameters of straight and curved-tooth rightngle bevel pinions. *Fig.* 3 shows a schedule of recomended maximum number of teeth for carburized and round spur pinions.

The simplified equations solved by *Fig.* 1 are, for pur pinions (see Nomenclature),

$$D_P = 6.1 \sqrt[3]{\frac{P}{n_P R}\,\frac{1+m_G}{m_G}} \qquad (1)$$

nd for helical pinions

$$D_P = 5.4 \sqrt[3]{\frac{P}{n_P R}\,\frac{1+m_G}{m_G}} \qquad (2)$$

In *Fig.* 2, for straight-tooth bevel gears,

$$D_P = 9.2 \sqrt[3]{\frac{P\cos\gamma}{n_P}\,\frac{1+m_G}{m_G\sqrt{1+m_G^2}}} \qquad (3)$$

nd for curved-tooth bevel gears,

$$D_P = 8.14 \sqrt[3]{\frac{P\cos\gamma}{n_P}\,\frac{1+m_G}{m_G\sqrt{1+m_G^2}}} \qquad (4)$$

Actually, certain limiting simplifications have been made in the charted solutions (*Fig.* 2) of Equations 3 and 4. First, the face width has been taken as $F = A/3$. Next, a shaft angle of 90 degrees has been assumed, and the pinion pitch angle γ has been "built-in." When shaft angles other than 90 degrees are involved, Equations 3 and 4 can still be employed. When significant deviation from the condition $F = A/3$ occurs, the detailed calculation procedure recommended in the earlier article must be followed.

Nomenclature

A = Cone distance of bevel gears, inches
D_G, D_P = Pitch diameter of gear and pinion, inches
F = Face width, inches
m_G = Gear ratio ($m_G = N_G/N_P = D_G/D_P$)
N_G, N_P = Number of teeth in gear and pinion
n_G, n_P = Rotational speed of gear and pinion, rpm
P = Power, hp
P_d = Diametral pitch
R = Ratio of face width to pinion pitch diameter ($R = F/D_P$)
γ = Pitch angle of bevel pinion, degrees ($\tan \gamma = D_G/D_P$)

With respect to the number of teeth in the pinion of a gear pair, smooth running dictates that the greatest possible number should be specified. However, for adequate resistance to bending stress, coarser teeth, and therefore fewer, should be employed. The following equation is a recommended compromise of these diverging influences in terms of maximum number of pinion teeth:

$$N_{P\text{-}max} = 25\,\frac{1+m_G}{m_G} \qquad (5)$$

Although Equations 1 through 5 are based upon commonly accepted theories and will yield results of

DATA SHEET

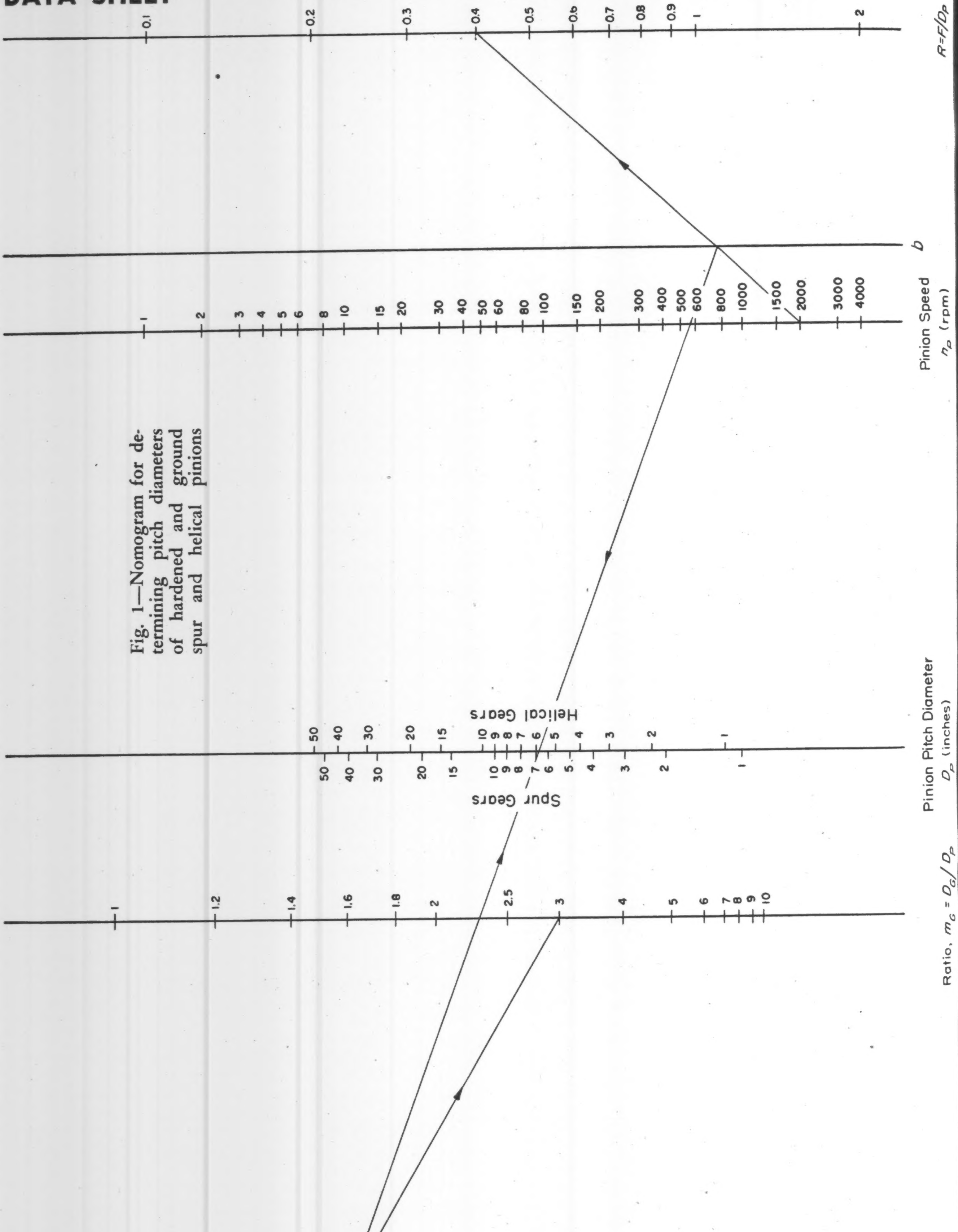


Fig. 1—Nomogram for determining pitch diameters of hardened and ground spur and helical pinions

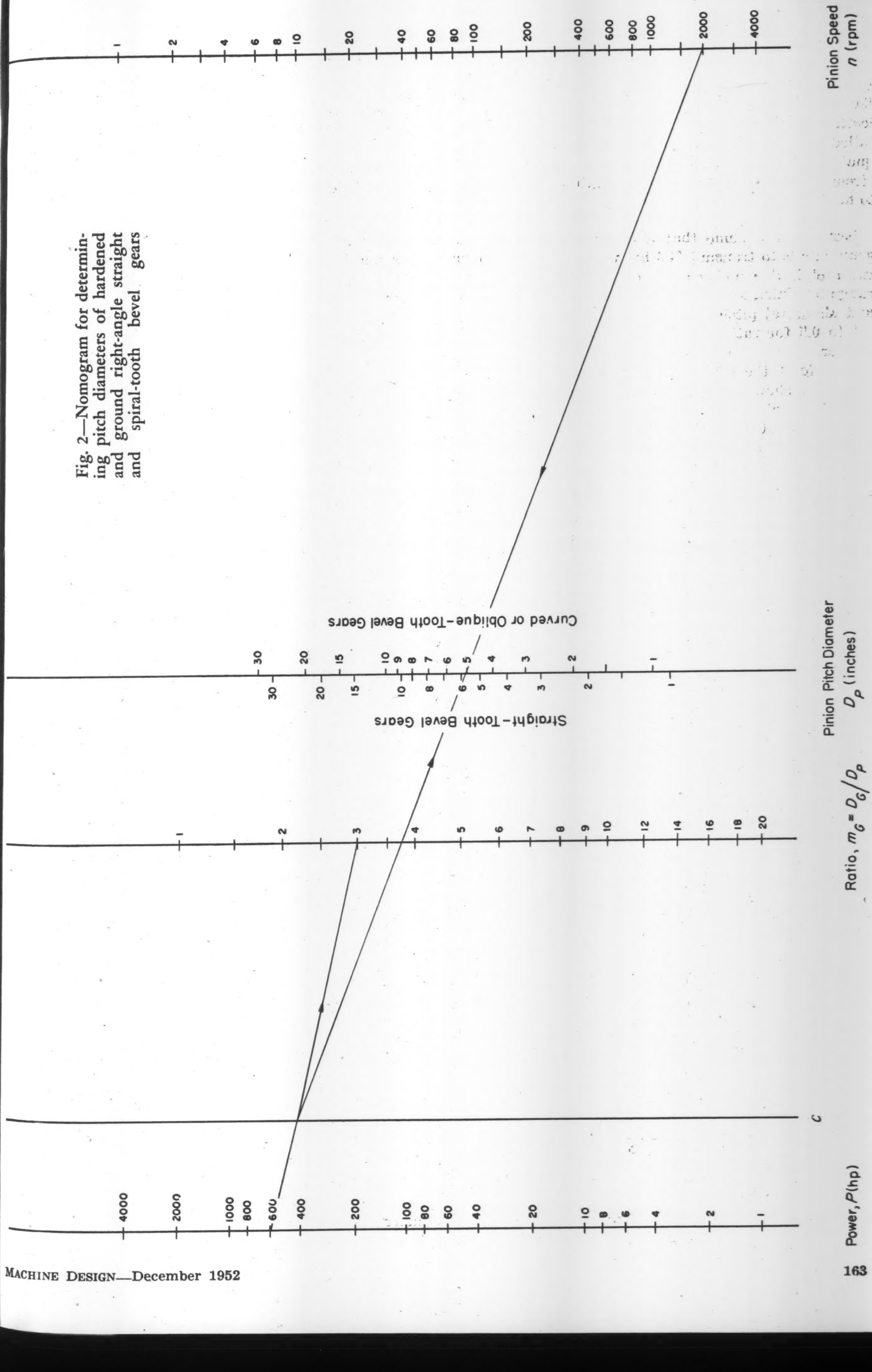


Fig. 2—Nomogram for determining pitch diameters of hardened and ground right-angle straight and spiral-tooth bevel gears

reasonable accuracy, they should be used only in preliminary studies. After the equations have aided selection of the probable best proportions, full and detailed calculations must be made to determine adequate design against the three criteria — bending strength, surface compressive strength, and resistance to heat.

Examples: Assume that a carburized and ground gear pair is to transmit 600 hp, with a gear to pinion ratio of 3, at a pinion speed of 2000 rpm. Find the range of pinion and gear pitch diameters, face width, and diametral pitch that would hold in the range of 0.4 to 0.5 for ratio of face width to pinion pitch diameter.

On *Fig.* 1 the first step is to connect $P = 600$ and $m_G = 3$, as shown. The intersection on unmarked scale *a* is then noted. Next, connect $n_P = 2000$ with, successively, $R = 0.4$ and 0.5, holding the two resulting intersections on scale *b*. Finally, join the reference point on scale *a*, with each of the two noted points on scale *b*. Read values at the two intersections on the scale for spur pinion pitch diameters, as follows: for $R = 0.4$, $D_P = 6.5$; $R = 0.5$, $D_P = 6.0$.

Then, the two sets of values are: $D_P = 6.5$, $D_G = m_G D_P = (3)(6.5) = 19.5$, $F = RD_P = (0.4)(6.5) = 2.6$; $D_P = 6.0$, $D_G = (3)(6.0) = 18$, $F = (0.5)(6.0) = 3.0$.

Next, the number of pinion teeth must be investigated. From *Fig.* 3, the recommended maximum number of pinion teeth for a ratio of 3 is 33. If this number is employed, diametral pitch P_d for the alternative designs so far developed would be $P_d = N_P/D_P = 33/6.5 = 5.08$ and $33/6.0 = 5.5$. Standard diametral pitches of 5 or 5.5 would be satisfactory for the alternative designs. However, recalculation and slight adjustment of some values would be necessary if $P_d = 5.0$ (instead of 5.08) were selected.

By similar procedures, many variations of this example can be quickly worked out to suit the initial conditions as well as those limitations or influences that are effective in a particular design.

If the requirements of the foregoing example ($P = 600$ hp, $m_G = 3$, $n_P = 2000$ rpm) were to apply to a straight-tooth right-angle bevel gear pair, the following steps would be taken. On *Fig.* 2, locate the intersection on scale *c* of the line joining $P = 600$ and $m_G = 3$. From this point project a line to $n_P = 2000$, and read $D_P = 5.8$ inches on the straight-tooth D_P scale. Other required factors can be calculated by conventional procedures.

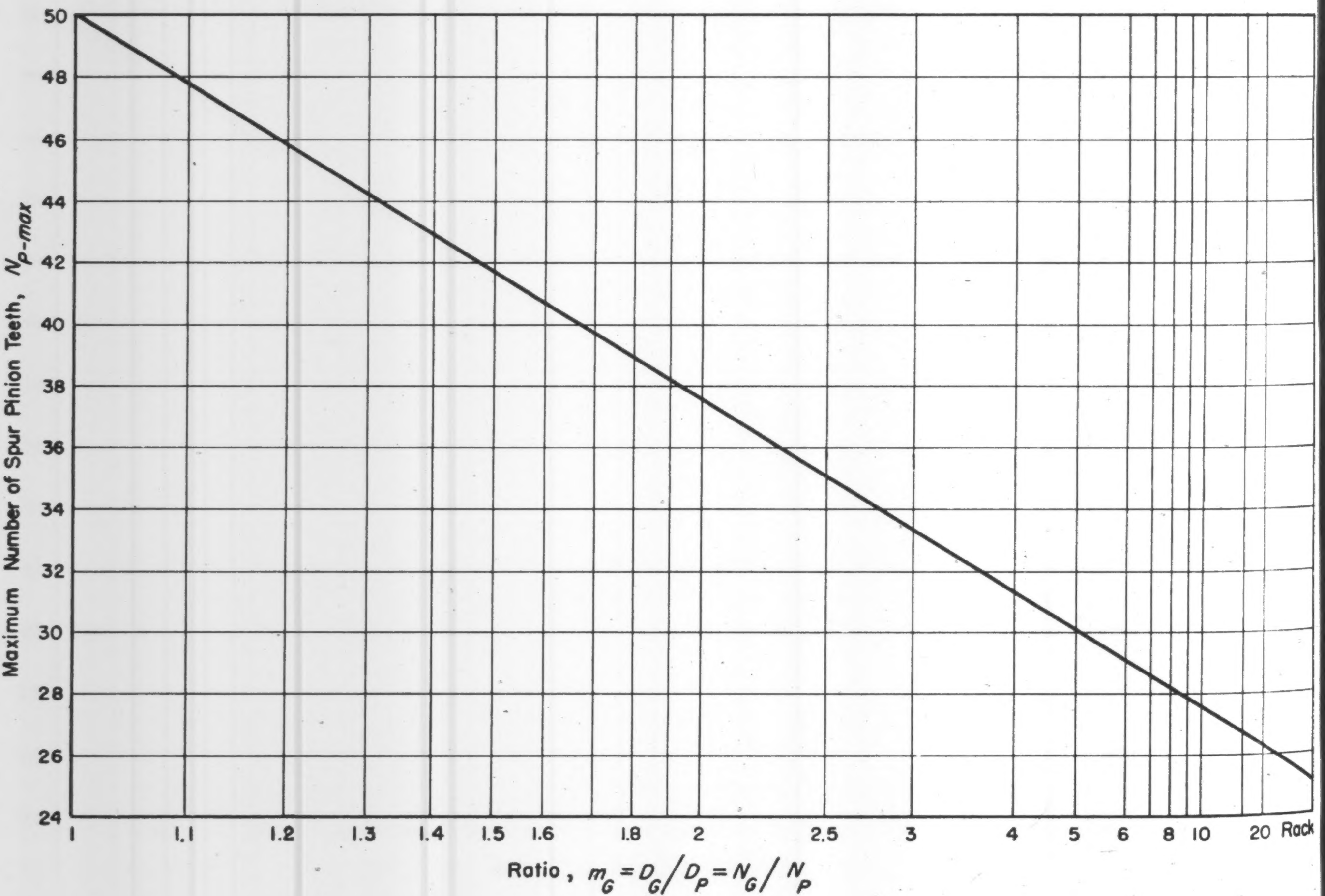


Fig. 3—Recommended maximum number of teeth for hardened and ground spur pinions from the standpoint of adequate bending strength

VITREOUS COATINGS today represent a family of protective coatings with unique properties and a wide range of application. Essentially glasses bonded to steel, these coatings are well-known as porcelain-enamel finishes for consumer products—but have equal importance in engineering uses where their function as a protective coating is primary and appearance is secondary. In this article, the uses of porcelain enamels and the various types available are presented. Subsequent articles will discuss service properties, design considerations and effects of processing on design.

A Designer's Guide to Vitreous Coatings

Types and Uses

By Robert L. Stedfeld
Associate Editor, Machine Design

PORCELAIN enamels have long been known as durable, decorative finishes for consumer products. But the whole range of vitreous coatings—porcelain enamels, ceramic coatings, glass linings and other "glass-on-steel" finishes—offer many possibilities to a designer in meeting a variety of exacting service conditions.

In three service areas, particularly, porcelain enamels or related vitreous coatings provide excellent protection: (1) acid, chemical and corrosion resistance, (2) high-temperature resistance and, (3) abrasion and wear resistance. Usually enamel coatings can combine several of these properties and, in addition, present an attractive appearance.

Thus, the porcelain-enamel coatings on the conventional household range are called upon to resist heat, food acids, wear, thermal shock and, occasionally, mechanical damage. In this example the service conditions are relatively mild but the same required properties, in much greater degrees, are available in porcelain enamels for industrial and engineering uses.

Vitreous enamels are difficult to separate into convenient classifications, either by physical properties or by service characteristics. Basically all porcelain enamels are the same—a glass fused to metal. But a specific slip is complex and may contain as many as fifteen different constituents. Some of these ingredients are refractory materials—sodium silicate, magnesium silicate or feldspar—which form the basic glass. Others, such as fluxes, opacifiers, suspending agents and electrolytes, are often minor in quantity but have important effects on the behavior of the enamel as it is processed. Variations are infinite and can provide a wide range of physical properties for different service conditions. Despite the complex array of enamel formulations, a few broad groups stand out.

Enamels applied to low-carbon sheet iron or sheet steel are more commonly used than any other type. These sheet-metal enamels are distinguished by being applied by the "wet process," in contrast to enamels for castings, which may be applied by either the wet or "dry process." Although it is possible to use some cast-iron enamels on sheet metal and vice versa, the practice is not common, since enamels are formulated for specific service and processing requirements.

Sheet-Metal Enamels

Enamels formulated for "decorative" use on sheet metal are employed for a variety of functional engineering requirements, since these enamels can have high acid resistance, relatively high heat resistance and structural strength, and excellent abrasion and wear resistance. Special enamels, considered separately, have been developed for unusual service conditions, but standard enamel formulations will often prove to be entirely satisfactory.

Basically, almost all final coatings for sheet-metal are composed of several separate enamel layers. First, a ground coat is applied and fired, and then one or more cover coats are used. Occasionally, an overglaze, dust-coat or over-spray may be applied.

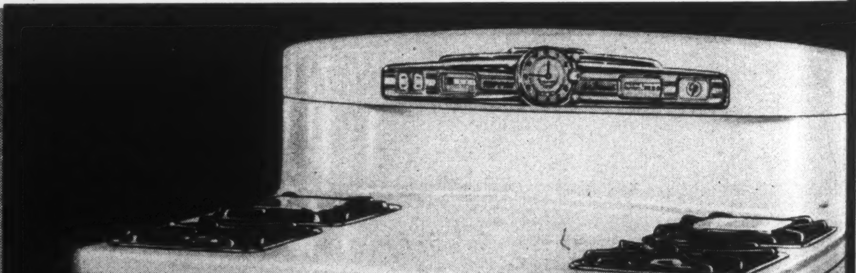
Ground Coats: The primary function of a ground coat is to provide a strong bond between the base metal and the cover coat. Thus, the ground coat is formulated to have high adherence to the metal. In addition, the ground coat must "seal" the metal to prevent gas evolution during firing, and also must prevent chemical reaction between the metal and the cover coat.

The ground coat gains its adherent qualities from the use of cobalt oxide, often supplemented with nickel and manganese oxides. Cobalt oxide gives the characteristic dark color to ground coat enamels, ranging from dark blue to almost black. White or light-colored ground coats can be formulated, but are not usually as satisfactory in processing or final appearance.

Physical characteristics of a ground coat are rather carefully controlled, since resistance to thermal shock, impact and chipping must be high. A smooth, even coat should result upon firing, and the ground-coat enamel is selected to have a wide firing range to accommodate variations in processing. Thermal and physical properties must be matched to those of succeeding coatings of enamel.

Quite often, a ground is the only enamel coating applied to the part if service is the primary consideration and appearance is secondary. For this type of service, acid-resistant ground coats can be formulated, or an over-spray of acid-resisting enamel applied.

To meet these rather stringent requirements, conventional porcelain-enamel ground coats usually contain at least eight and sometimes as many as ten or twelve components. Low, medium and high-tempera-



Heat, food acids, abrasion and impact must be resisted by the porcelain enamel coating on a household range. To meet these service conditions, the range chassis is first dipped in a ground coat; glossy black-edging enamel is then applied; and a white stipple is sprayed on some sections of the chassis and other parts not receiving a cover coat. After the ground coat is fired, white titanium enamel is applied as a cover coat, is then brushed, and fired.

Photo, courtesy Tappan Stove Co.

ture firing frits are often combined to provide a coating that matures at the proper firing temperature.

"Hard" ground coats, fired at about 1600 F, have been standard for a number of years, but are giving way in many cases to "softer" ground coats fired at 1500 to 1550 F. These lower temperatures decrease the possibility of distortion, warping or sagging of the steel, especially in nonenameling grades. By using soft ground coats, metal thickness can occasionally be reduced. Continual effort is being devoted to developing coatings which fire at lower temperatures, and coatings have been developed with firing temperatures as low as 1350 F.

As a guide to the acceptability of a ground-coat enamel, coefficient of thermal expansion is sometimes used, but should not be accepted as an absolute criterion. For best resistance to crazing, for example, a ground coat of low coefficient of expansion is usually chosen. Conversely, a high coefficient of expansion seems to aid thermal shock resistance and resistance to chipping on small radii or beads. Impact resistance and resistance to hairlining, however, do not seem to be affected by coefficient of expansion of either the ground-coat or cover-coat enamel.

Cover Coats: In its broadest meaning, "cover coat" denotes any final coating applied either over a ground coat or as a single coating over sheet metal. Cover coats may have a number of functions. Thus a glossy white appearance is highly desirable in an enamel formulated for many kitchen appliances. In addition a cover-coat may be called upon to provide protection against acids and chemicals, abrasion and impact, high temperatures, thermal shock or weathering. Thousands of special "cover coats" have been developed to meet particular requirements. But in enamelers' parlance, a "cover coat enamel" is often understood to refer to the "standard" white and colored opaque enamels which appear as durable, decorative finish coats on appliances, signs, etc.

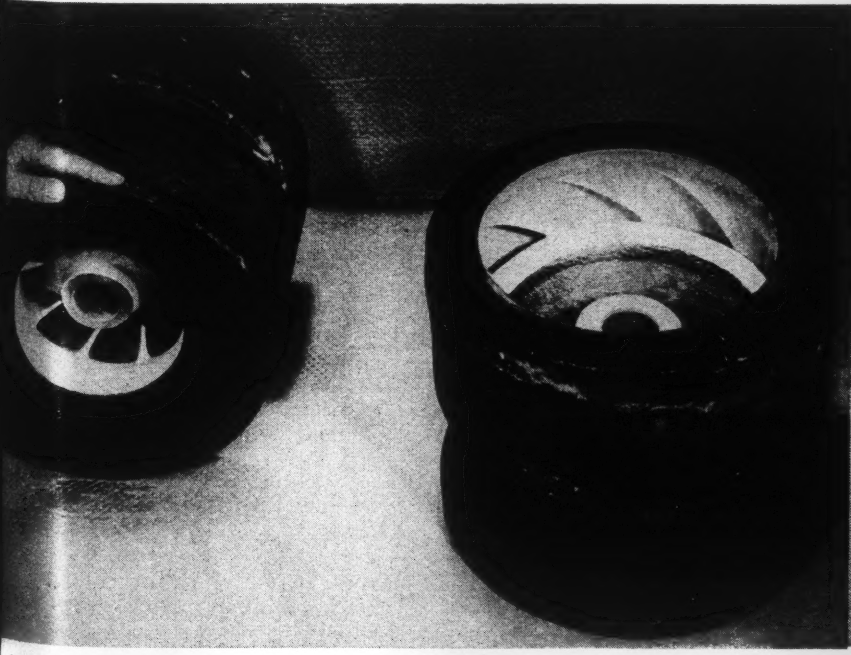
WHITE OPAQUE ENAMELS: By far the greatest quantities of porcelain enamel used are white opaque enamels. Of these, enamels using titanium dioxide as an opacifier—so-called titanium enamels—are the most prevalent. Zirconium and antimony frits are used for special applications, but have largely been superseded by the titanium type. Primarily, this large use is due to two factors: high opacity which can be achieved at low application weights, and excellent acid resistance.

In contrast to the older zirconium and antimony enamels, titanium enamel can provide sufficient opacity at about half the coating weight per square foot. Thus only one cover coat of a titanium-opacified enamel is necessary, as contrasted to two or more coats required to obtain sufficient opacity or reflectance with the older enamels. Obviously, production costs are greatly reduced. Thinness of the coating, however, and the moderate flow of titanium enamels during firing produce less adequate coverage of slight defects. Consequently these enamels must be of excellent quality.

Acid resistance of titanium enamels is slightly lower than the antimony frits, but higher than the zirconium frits, which are not considered acid resisting. Titanium enamels can be formulated in most degrees of acid resistance. Antimony frits can be similarly formulated, but acid-resisting antimony frits are normally utilized as either a second cover coat over a nonacid-resisting base coat or as a dust coat over a partial coat of nonacid-resisting enamels.

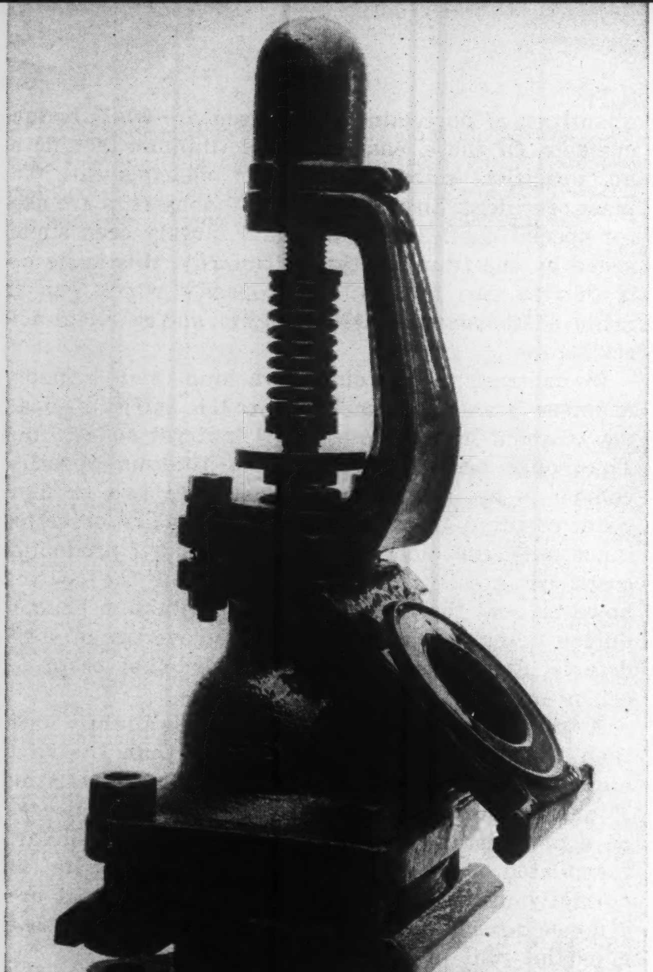
All types of white, ranging from blue white to cream white, are available. By the addition of suitable color oxides, slight variations and some pastel shades can be produced, but generall titanium enamels are difficult to color and undependable in final shade. Antimony and zirconium-opacified enamels can be produced in practically all pastels and deep colors. Gloss of titanium enamels is higher than either of the other two types.

Physical properties of titanium enamels are excellent. Since thin coatings can be applied, resistance



Reduction of flow friction is the function of the porcelain-enamel interior coating on this deep-well pump housing. Although a white ground coat is shown for contrast, the actual enamel is dark-colored with a high gloss that promotes the fastest possible flow. Besides reducing friction, the enamel also protects the casting against rust and deterioration.

Photo, courtesy Barrows Porcelain Enamel Co.



High acid resistance is accomplished by glass lining the cast-iron body of this pop safety valve. The glass lining, which is also applied to the steel stem supporting the head and other interior parts, resists all acids except hydrofluoric and hot, concentrated phosphoric. It can also withstand temperatures up to boiling and 150-psi pressures.
Photo, courtesy Pfaudler Co.

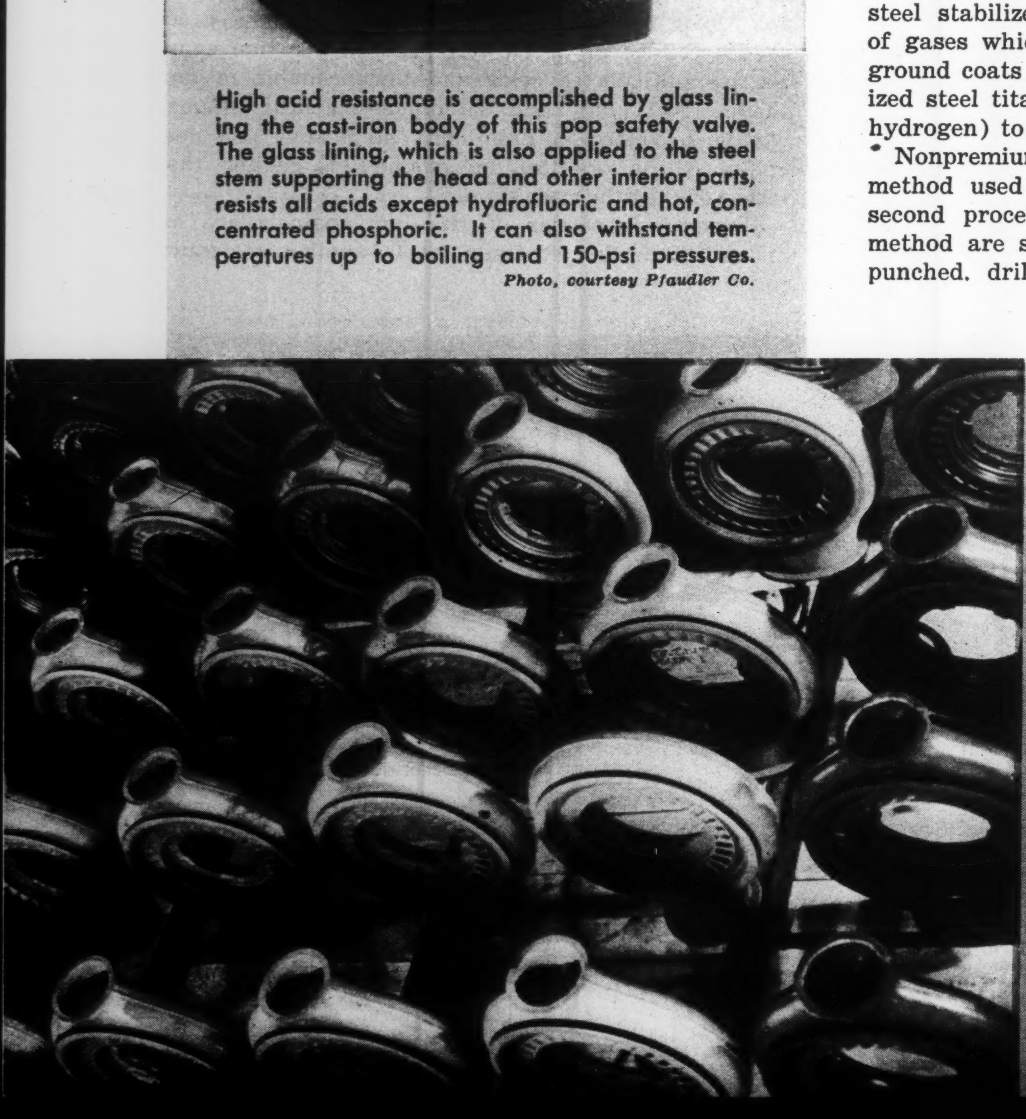
to chipping and mechanical failure is high. Resistanc to impact is good on flat surfaces, but poorer than th other two types on small radii. Wear and abrasio resistance is also high. Thermal shock characteristic of titanium enamels are favorable, but titaniu enamels are slightly more susceptible to warpage o the part while being fired and to chipping on smal radii.

Low-Temperature Firing Enamels: Titaniu enamels which can be fired at about 1350 F are relatively new development. Since these enamels fir at a much lower temperature than "harder" grades tendency of the metal to warp or sag is lessened, an gas evolution is minimized. Further developments i this area may lead to more extensive use of nonenameling grades of steel, since present objection to the use of cold-rolled steel stem largely from it behavior during firing.

One-Coat Enamels: Another, and newer, development is the "one-coat" enamel, a titanium frit applie to the metal without benefit of a ground coat. Advantages of the one-coat enamel are many. Thicknes of the enamel coating can be reduced to approximately 0.003-inch, as compared with almost 0.03-inc sometimes necessary for multiple coats. This thi coating resists chipping better than thicker enamels In addition, since only one coating must be spraye and fired, substantial reductions in processing cost are possible.

Two methods have been used to obtain one-coa coverage. The first of these involves use of a specia steel stabilized with titanium to prevent formatio of gases which cause blisters and defects. Normall ground coats perform this function, but in the stabilized steel titanium "binds" the carbon (and possibl hydrogen) to prevent gas evolution.

Nonpremium steel, plated with a nickel flash, is th method used to obtain one-coat coverage with th second process. Titanium enamels applied by thi method are so thin that they can be sheared, bent punched, drilled or sawed after enameling withou



Ceramic-coated, these turbosup charger nozzle boxes must re extreme heat and corrosive gas A ceramic coating 0.001-inch thi is applied on high-alloy steel prolong its life. The parts shown in varying stages of pr essing, with the finished parts the extreme right-hand row.
Photo, courtesy Bettinger Co

difficulty. In general, the lower firing enamels have been more successful in this application than conventional-temperature enamels.

Both of these methods are still in the tentative stage, although both have been tested with success in production operations. Main drawback to both methods is the special materials or processing necessary, which necessarily limit present applications.

COLORED ENAMELS: In addition to white opaque frits, colored frits and nearly transparent frits are available, from which almost any color in the rainbow can be produced by adding color oxide tints or ceramic pigments. Dark colors, such as blue or black, are made from colored frits, pastel shades from white opaque frits, and opaque colors from semitransparent frits. Beading and black-edging enamels, for example, are usually produced from a black frit to which a black color oxide is added.

Production of colored enamel coatings require much experience and close processing control. Color matching especially is a difficult task, requiring careful handling of not only enamel formulation but also thickness of application, firing temperature and other process variables.

MISCELLANEOUS DECORATIVE ENAMELS: In addition to colored enamels, many combination effects and special surface finishes can be attained by using two or more enamels or by using special processes. Thus, in the standard enamels a number of different surface textures are available. Mottled colors are accomplished by firing two colored enamels at the same time. Speckled or stipple finishes are the result of spattering one color on the fired coating of another. Woodgrain or marble patterns can be "printed" with a special graining roll. Offset or silk-screen printing and ceramic decalcomanias are often used for signs, con-

Terms Used in Porcelain Enameling*

beading—The application of enamel, usually a contrasting color, to the edge or rim of hollow-ware articles.

bisque—A coating of wet-process enamel which has been dried but not fired.

black edging—A coat of enamel added to the bisque or fired ground coat for the purpose of producing a black finish coating over a wide edge or given area. After application, the cover coat bisque, is brushed away from this area before firing, thus exposing the black enamel coating.

blister—Bubble formed in enamel during fusion which remains when enamel solidifies. An unbroken blister is usually called a glass eye.

brushing—Removal of bisque by means of a brush. Usually the process is used to remove cover-coat bisque to expose the underlying enamel layer.

bubble structure—Dimension and distribution of voids within the fired enamel.

chalky, or chalked—The condition of an enameled surface which has lost its natural gloss; a severe etching.

checking—Raised lines on cast-iron enamels caused by cracking of the ground coat underneath.

chipping—A spalling or breaking away of fragments of enamel surface.

color oxide—A material used to impart color to porcelain enamel.

copperhead—Small freckle or pimple-like spot, reddish brown in color, sometimes found in the fired ground coat.

cover coat—A porcelain enamel coating applied over a ground coat or other cover coat.

crazing—Appearance of fine cracks in the enamel layer.

devitrification—The loss of the vitreous properties of an enamel by its becoming crystalline in structure.

dimple—A cone-like depression, somewhat larger than a pinhole, in the fired enamel surface.

dipping—Process of applying enamel by immersing the metal shape for a short time in enamel slip. In dry-process enameling, the method of applying enamel by immersing the heated metal shape for a short time in the enamel powder.

dredging—The application of dry enamel powder to hot ware by sprinkling or sifting.

dry-process enameling—The applicatior of drp powered enamel to heated ware.

dust coat—A relatively dry enamel slip sprayed in a thin layer.

dusting—(1) In dry-process enameling, the application of dry enamel to the hot ware.

(2) In wet-process enameling, the piling up of almost-dry enamel.

edging—(1) The process of removing bisque enamel from the edge of a piece of ware to expose underlying fired enamel.

(2) The application of different colored enamel to the edge.

enameling iron—Sheet iron suitable for porcelain (vitreous) enameling. Either a very low carbon steel or open-hearth iron.

firing—process of fusing the porcelain or vitreous enamel to the metal base.

fishscaling—An imperfection which sometimes occurs in sheet metal enamel. Small particles, somewhat resembling the scales of a fish, detach themselves from the enamel layer. This can happen a considerable length of time after the enamel has cooled, in which case it is called "delayed fishscaling," in contrast to the term "process fishscaling" which is used to describe fishscaling occurring during the processing.

flatware—Sheet-metal parts for porcelain enameling which are essentially flat, although such parts may have rims or flanges or may be embossed.

frit—Small friable pieces of vitreous enamel. The result of quenching and shattering the molten material in a water bath. Later milled with other additives to form a slip or powder.

gloss—The shine or luster of a smooth enameled surface.

graining—Production of a decorative finish by transferring a pattern to the enamel surface by means of a colored mixture of ceramic oxides with oils.

ground coat—The first layer of enamel applied to sheet metal, containing ingredients specially designed to produce adherence to the metal.

ground coat boiling—Evolution of gas during firing of ground coat with resultant raised bubbles.

hairline—Dark line in enamel due to ground coat showing through the cover coat, without any break or crack in the enamel.

hardness—(1) Relative resistance of the enamel surface to deformation from pressure or abrasion.

(2) The refractoriness of an enamel, that is, the extent to which it resists the heat before fusing.

hiding power—The power of a coating to obscure or hide completely the surface over which it is applied.

hollow-ware—Deep - drawn sheet - metal parts usually kitchen utensils such as refrigerator pans, pot, kettles, etc.

jumping—The chipping off of pieces of the first enamel coat during subsequent heating to fire cover coats. Caused by foreign material on the iron or in the enamel.

lamination—Areas where a metal occurs in layers due to blowholes, slag, or impurities in the ingot. If laminated areas are large, metal blisters are often formed during pickling or ground-coat firing.

metal blister—Bloating of the enameling iron sheet during any heating of the metal.

opacifier—Any material which gives or adds opacity to the fired enamel.

opacity—Power of enamel to reflect diffusely a high percentage of incident light.

orange peel—An irregularly wavy enamel surface similar to the surface of an orange.

overglaze—A fusible mixture of metallic pigments and fluxes, usually colored, applied by screen, brush or spraying to the already fired ware which is then given an additional firing.

pinhole—Pinpoint-like depression in the surface of the enamel, sometimes caused by overfiring. Pinholes are smaller than dimples.

pop-off—Detachment of a small area of cover-coat enamel during drying or firing.

scab—Imperfection in enameling steel or iron castings, having the appearance of a loose piece of metal, tongue, or flap rolled into the sheet surface.

scale—Oxide on the surface of the metal, either remaining from the manufacturing process or purposely created by heating the metal to redness.

slip—The liquid enamel suspension.

slushing—The coating of ware with an enamel slip by pouring or throwing the slip onto the ware. The excess enamel may be removed by either draining or shaking.

softening temperature—The temperature at which the porcelain enamel glass begins to flow.

spalling—The failure of a porcelain enamel due to stresses induced by extreme temperature fluctuation, usually characterized by chipping or flaking.

warping—Change in the original contour of the enamel ware produced during firing.

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*Adapted from "Tentative Definitions of Terms Relating to Porcelain Enamel" (C286-51T), 1951 *Supplement to Book of ASTM Standards,* American Society for Testing Materials; some definitions adapted from *The Enameler's Dictionary,* Ferro Corp., 1947.

trol dials, instruction plates and similar applications.

Abrasion-Resistant Enamels: Although standard cover coats have excellent resistance to abrasion and wear, special coatings can be manufactured with an exceptionally hard surface and high gloss. Developed for materials handling, this type of enamel reduces surface friction, is resistant to scratches and wear, and can be used for outdoor applications in which weathering is a factor.

Nonferrous Metal Enamels: Dating back thousands of years, porcelain enamels for precious metals and copper are now largely confined to art enamelware. More recent developments, however, are enamels for aluminum and high-temperature coatings for molybdenum (discussed later).

Porcelain enamels for aluminum, although similar to standard enamels for ferrous metals, can be applied in one or two coats. The final enamel coating may be sheared, sawed, drilled or punched without detrimental surface damage. Enamels can be obtained in varying degrees of opacity, reflectance and surface texture, and have good chemical and corrosion resistance.

Main difficulty in the processing of aluminum has been the low critical temperature of the metal. Although porcelain enamels for aluminum are fired at about 980 F—compared to 1550-1600 F for standard sheet-steel enamels—this temperature is within several hundred degrees of the critical point for aluminum. At firing temperatures, therefore, the metal has a tendency to warp or sag.

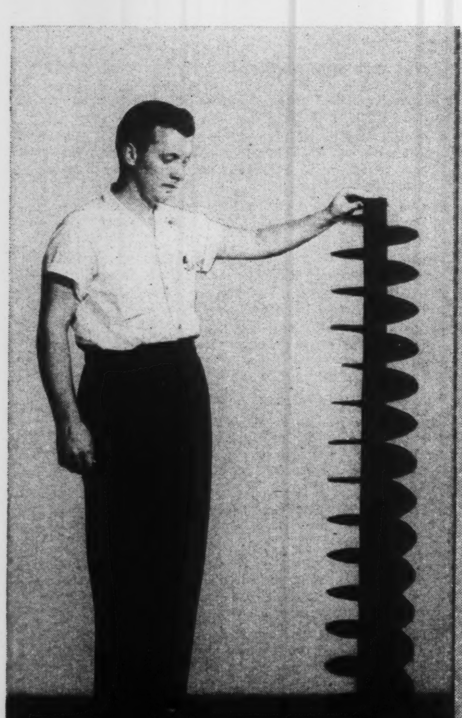
Successful coatings have been attained in production operations on aluminum sheet and extrusions. Wrought alloys 2S, 3S, 53S and 61S, and casting alloy 43, are most satisfactory, and available enamels are specifically designed for these metals.

Porcelain enamels for aluminum will withstand direct immersion in water from 900 F, permitting the use of a heat-treat and quench after firing if the coating is not heavy. Enamels are not affected by standard salt-spray tests and have a dielectric strength of 500 volts per mil. In other respects they compare favorably with porcelain enamels for ferrous metals.

Cast-Iron Enamels

Most of the development of cast-iron enamels has been for range parts and sanitary ware. These enamels can give an exceptionally thick coating and, of course, must be used when cast parts are to be covered.

Porcelain enamels for cast iron are processed by two methods, the wet process or dry process—thus determining the type of enamel. Hard, acid-resisting grades are available, as well as enamels which are quite soft and have a relatively low resistance to abrasion and acids. Range of colors is fully as wide as the range in sheet-metal enamels. Generally quite similar to sheet-metal enamels, enamels for castings are, however, more complicated in composition and are consequently more sensitive to variation.



Providing a hard, glassy surface, the porcelain enamel on this conveyor screw resists abrasion and prevents sticking. Wet fast-setting gypsum slurry often sets and cakes. Since it does not stick to the smooth enameled surface of the conveyor screw, it is kept moving at a uniform rate. Porcelain-enameled sheet-iron replaces stainless-steel formerly considered necessary to prevent rust and resist abrasive action.

Photo, courtesy Barrows Porcelain Enamel Co.

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Hot gases at 2000 F are conducted by this chamber for a petroleum-refining burner unit. Made of Type 309 stainless steel, the ceramic-coated steel chamber is expected to last about four years, at least double the life of previous uncoated chambers.

Photo, courtesy Solar Aircraft Co.

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Wet-Process Enamels: Wet process enamels are usually used for lightweight small and medium-sized castings. A ground coat may or may not be used, and need not contain cobalt oxide since adherence is thought to be the result of mechanical bonding rather than chemical interaction. Often the ground coat is merely a modified cover coat.

Wet-process porcelain enamels for castings can be conveniently separated into two grades: the leadless enamels which greatly resemble sheet-metal cover coats; and the leaded varieties which are softer, with less acid and abrasion resistance. Firing temperatures for both are in the range of 1200-1400 F.

Leadless enamels may be of the zirconium, antimony or titanium-opacified types and, in properties and uses, are quite similar to the sheet-metal enamels.

Leaded enamels, however, have many differences. These enamels are easily worked, since the presence of lead oxide aids fusibility and working properties. Surfaces of high-lead enamels are very brilliant but, being softer, will not withstand as much mechanical abuse. In addition, these enamels are quite soluble and are not suitable for applications in which the lead-bearing enamel might come in contact with food. For these reasons, leaded porcelain enamels have largely been replaced by leadless types, although their easy working properties make them suitable for occasional difficult jobs.

Dry-Process Enamels: Used chiefly on heavy castings, dry-process enamels are also occasionally employed on small parts where an exceptionally thick coating of enamel is desired. Coating weights are several times as great as those attained with sheet-metal enamels, and extremely thick coatings can be built up.

Ground coats, which protect the iron from oxidation and scaling while it is being heated, are always used. Often called "slush," "bond," or "grip" coats, they are flowed on to the casting as a thin, watery slip before the enamel is heated for dredging or dipping, and are thus fired at this time.

Cover coats bear a great resemblance to the wet-process enamels for castings, except that dry-process coatings are generally more brilliant. Leaded and leadless grades are both available, the latter usually being the antimony or titanium types of enamel. White cover enamels are by far the most prevalent, but practically all colors can be produced by addition of color oxides, stains, colored frits or a color glaze.

Ceramic Coatings

"Ceramic coatings"—a term applied to enamels designed for high-temperature protection of metals—differ in many respects from standard porcelain enamels. Coating composition is still basically that of a glass or vitreous coating, but specific components are radically different. Some types have a hard, glossy green finish, and others a dull, full-matte gray finish—both quite different from standard enamels. In addition, they are primarily designed for high-temperature steels, and are fired at 1800 to 2000 F.

Service area is in the temperature range of 1200 F and above, beyond the capabilities of standard porcelain enamels. For high-temperature service, ceramic coatings have three practical applications: (1) lengthening the service life of high-temperature alloys, (2) extending the temperature service range of others and, (3) permitting the substitution of low-alloy steels, less rich in strategic elements.

As yet, these coatings are available mostly for sheet-metal parts. On low-alloy steels their prime function is to prevent oxidation which may occur in days, hours or even minutes at high temperatures. On high-alloy steels, ceramic coatings protect against deterioration in the form of scaling and intergranular corrosion caused by the action of hot or flaming gas.

Of the thousands of formulations which have been developed, only a few are being used in production today. These include the National Bureau of Standards A-417 and A-418 coatings, the Ryanco A-418C which is a relatively new coating, the Solaramic 52-2C and 5210-2C, and Chicago Vitreous Enamel Product's SL-13290. The A-418, SL-13290, 52-2C and 5210-2C have been approved by the Air Force for application to turbosupercharger nozzle boxes.

First coatings, announced by NBS in 1943, were the A-19 and A-31. The A-19 was a single thin coating designed to protect low-carbon steel in air at temperatures to 1250 F for extended periods of time. Only 0.002 to 0.003-inch thick, the coating was chip and crack-resistant. Although satisfactory in a number of applications, the two coatings were superseded by later developments.

A-417 Coating: Continuation of research produced the A-417 coating, in production since 1950. Applied in single-coat thicknesses of 0.001 to 0.002-inch this coating has so far been used mainly with Inconel and 19-9DL alloys, although it has been successfully applied on other alloys.

A-417 coated Inconel has been heated continuously to 1650 F for 500 hours in air with some loss of initial properties but no failure of the coating. And in actual service, A-417 type coatings on type 321 stainless steel and 19-9 DL exhaust headers for aircraft piston engines have withstood temperatures of 1200 to 1500 F, with localized high-velocity gas temperatures of 1800 to 1900 F. The coating gives promise of being successful on jet engine parts, and seems to have an indefinite service life at lower temperatures encountered in aircraft heat exchangers and exhaust pipes.

Resistance to flow at high temperatures is good, as is thermal shock resistance. The coatings adhere well, even after prolonged heating, and are reported to cover edges and welds without burning off.

A-418 and Ryanco A-418C: These two coatings, still later developments, are improved versions of the A-417. The Ryanco A-418C, for example, is formulated for temperatures up to 1800 F. Only recently announced, the coating is claimed to be unaffected by thermal shocks encountered in engine exhaust systems from −70 F to 1700 F.

Solaramic Coatings: Independently developed in a number of different formulations, Solaramic coatings are semimatte ceramic coatings, usually applied in thicknesses of 0.001 to 0.002-inch. Burner tubes and jet-engine combustion-chamber liners of Inconel and type 321 steel have shown a service life of 550 to 600 hours—completely satisfactory for the application. Burner-unit chambers, conducting hot gases burning at about 2000 F but subjected to outside cooling are expected to average about four years of service life.

These coatings are quite flexible, and a Solaramic-coated piece of foil can be bent, folded and twisted without serious damage to the coating. A standard test for coated parts is to bend them through 90 degrees, after which the sample must retain sufficient coating to provide protection for 50 hours of thermal shock testing. Parts can be spot-heated with an oxy-acetylene torch to 1700-1800 F and water quenched for 10 cycles. Similar tests of thermal shock resistance, cyclic heating resistance and fatigue resistance at high temperatures have been conducted. Data on these properties will be found in a later article.

Coatings for Molybdenum: Being one of the high melting-point metals (4750 F), molybdenum offers possibilities for jet engines and is one of the more available of these metals. But molybdenum is subject to rapid oxidation at these high temperatures. Various coatings have been developed for molybdenum both as sheet-metal and castings. The latest, a chromium and glass coating developed at NBS, has very high temperature resistance. This coating consists of a glass-free chromium base coat, a glass seal-coat and a third seal-coat of a lower melting-point glass. Subjected to oxidation tests under tension, this coating lasted for 1000 to 3000 hours at 1500 to 1800 F. In a flame test at 2800 F under no load, protection for 7 hours was attained—sufficient for some applications. Although complete information is restricted, ceramic coatings are being tested on molybdenum jet-engine buckets—an extremely high-temperature application.

Glass Linings

"Glass linings," "glassed steel" and other "glass coatings" form another specialized family of porcelain enamels. Closely following the development of the process industries, glass linings are formulated mainly to withstand chemical attack at moderate temperatures and pressures.

Some "glass linings" are no more than minor modifications of standard porcelain enamels, processed in the same way and having much the same properties. Others, however, have been formulated to resist (1) all acids except hydrofluoric and hot, concentrated phosphoric at room and elevated temperatures, (2) moderately alkaline solutions (pH 12) up to the boiling point without reduction in acid resistance and, (3) the highly corrosive action of water at temperatures up to boiling and hydrostatic test pressures of 300 psi. The first two glasses are used on equipment with internal pressures up to 250 psi and occasionally 500 psi in small sizes.

Glass linings developed for the process industries, typified by the first two enamels mentioned, are usually employed for heavy equipment which must withstand the weight of large amounts of liquid. Thus 13,000-gallon glassed-steel tanks have been made (35,000 gallons for mild solutions). Metals used are usually steel plate from 3/16 to 1 inch thick, and cast iron for fittings, pump parts and other smaller components. Both the wet and dry process are employed, and firing in inert atmospheres is fairly common. The dry-process glass coating is usually thick—generally greater than 0.025-inch—and may consist of from three to seven coats.

To resist corrosive action, hot-water tanks require the third type of glass applied by the wet process on standard-gage enameling iron.

Summary: For service as protective coatings, porcelain enamels are available in a multitude of formulations. Although composition of an enamel can be varied widely, general types which may be used are:

SHEET-METAL ENAMELS: Usually consist of a ground coat and one or more cover coats; cover coats are white opaque, low-temperature firing, one-coat, colored, and various decorative enamels; abrasion-resistant and nonferrous-metal enamels are also available.

CAST-IRON ENAMELS: Either wet-process or dry-process enamels, with leadless or leaded grades in each type.

CERAMIC COATINGS: Among the better known heat-resistant coatings are the A-417, A-418 and Ryanco A-418C, and the Solaramic coatings; coatings for molybdenum are being tested.

GLASS LININGS: Formulated especially for acid, alkali and chemical resistance.

To have a basis for evaluating and selecting the type of coating to be used, the designer must have comparative information and data on the service properties of these coatings. These data—information on optical properties, acid and chemical resistance, thermal properties and mechanical properties—will be presented in a subsequent article. A third article will cover selection of a base metal, processing considerations in design, and design for enameling.

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QUALITY CONTROL METHODS

Their Use in Design

To set realistic drawing tolerances, process natural tolerances must be known. Without control many precision processes are never fully utilized. This article will assist in determining practical tolerances and assuring the most easily measurable specifications

By Dorian Shainin
Chief Inspector
Hamilton Standard Div.
United Aircraft Corp.
East Hartford, Conn.

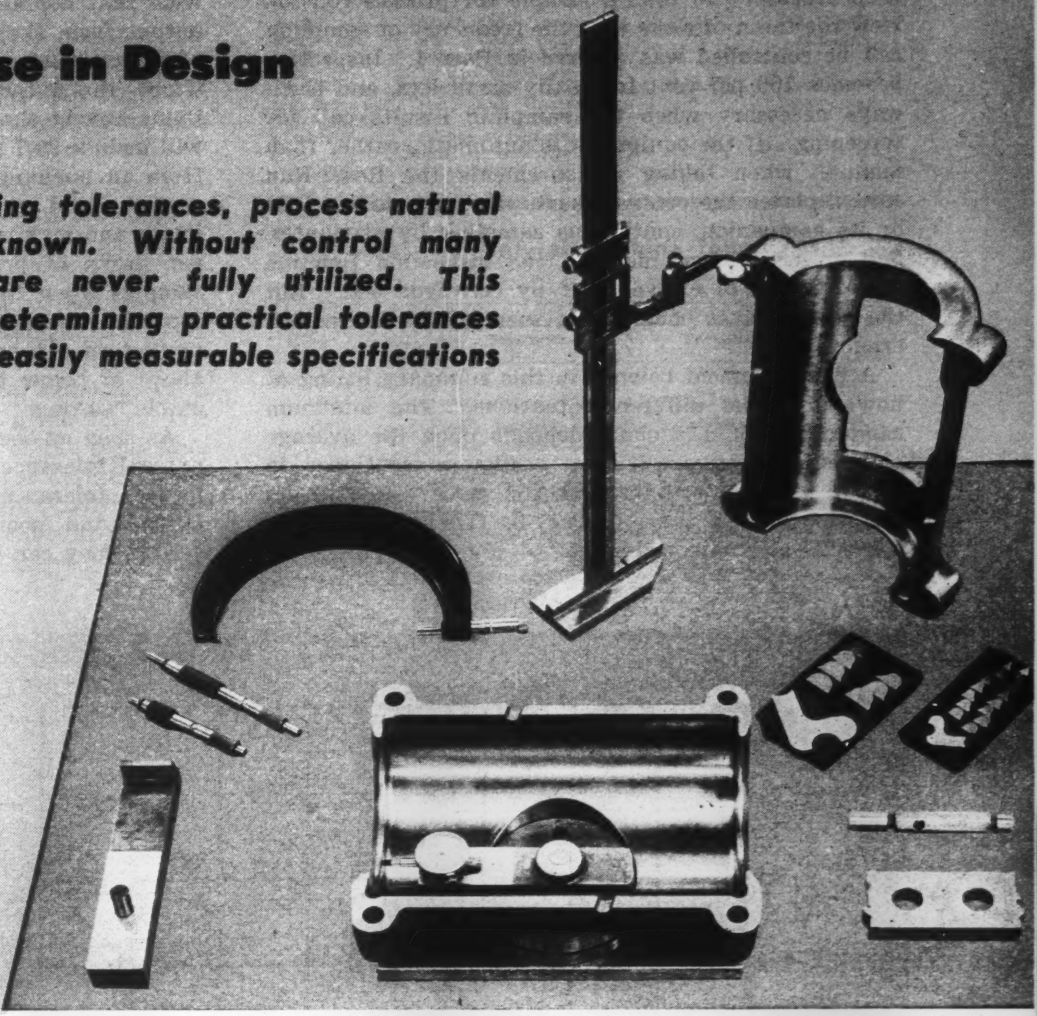


Fig. 37—Some dimensions on the two halves of this aircraft propeller hub can be checked by measurements (variable). Other requirements are most practically checked by go and not-go methods. The chart of *Fig.* 39 is excellent for controlling these attribute dimensions in production

Part 6—Processes and Natural Tolerances

When faced with the idea that SQC would help his plant with some design and manufacturing problems, a man might agree that these techniques would be useful for certain industries. And then he counters, "But our business is different."

Up to around 1942, electrical, textile and munitions manufacturing had benefited from the scientific control of quality. Almost every other industry had spokesmen quoting the foregoing reaction. Today, however, a list of over 5000 concerns in virtually every type of manufacturing activity, attests to the wisdom of the idea. Even service organizations are finding applications.

Businesses *are* different. So are processes within a plant. But each has characteristic, unavoidable variation in product quality. So SQC can help because it analyzes variation, *Fig.* 37—shows the *natural* tolerance.

Earlier in this series, some of the basic statistical tools for jobs in general categories were discussed, as listed in TABLE 4. To this can be added that whenever it is necessary to destroy in testing, a sampling plan by variables should always be investigated. There are other qualifiers for this table. Production rates have an effect on sample sizes and on how often it is necessary to take a sample for process control. How the tie-in of risks with the frequency of sampling can be controlled was covered in Part 4. Inspection becomes 100 per cent for really small lots, and is always necessary when the sampling results call for screening. If the equipment is automatic, rather than manual, when taking measurements the Reset-Run card replaces the control chart. Continuous Lot Plot or its companion, continuous sampling by attributes, find an economical place in the inspection function when the parts arrive as if by conveyor belt. But the checks must usually run successfully within tolerance.

A final comment belongs in this summary listing of how to handle different situations. The minimum sample size of a p chart depends upon the average per cent defective. It is a weakness mentioned in Part 1 and made evident in the more complete description of this chart in Part 3. There is available a special alternate technique.

Regardless of whether the problem is stamping, turning, forging, assembling, plating, or any other method, the important factor of interest is the natural tolerance. Natural tolerance includes these characteristics—the built-in variation peculiar to the process; for measurable results, the spread six-deviations wide that contains 99.7 per cent of all the expected output from the stable process. It is also the range of per cent defective values of samples from a process where the output can be counted as so many bad items among the good. Again, it is the spread that will include 99.7 per cent of all such percentage values from an unchanged situation. Last, the natural tolerance would apply to the difference between the minimum and maximum number of bad spots per unit or per group of product that would be expected from samples when the operation is running in statistical control. These two cases correspond to the readings plotted on a p and a c chart. The variation extends above or below the average value, the unchanged or stable "setting."

As soon as one of these statistical tools reveals the natural tolerance, it can be compared with the specification tolerance, as in TABLE 5, and with regard to spread and position. When specifications are exceeded they can either be changed or, better yet, the

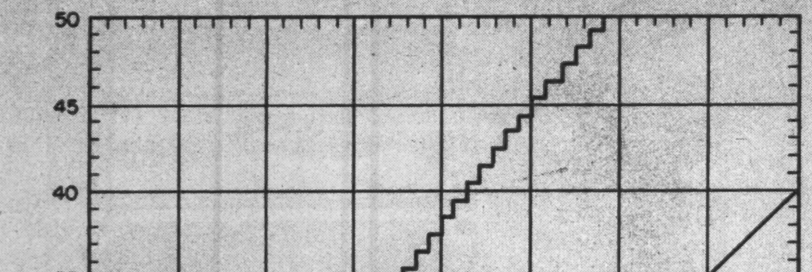


Fig. 38—Chart for position of control limits. Distribution of number of defects is not symmetrical. Limits are between digits to bring count of defects clearly in or out of control

process often can be changed. Most people may not agree. Their experience tells of many processes that were not easily changed. However, with simple statistical tools explained in a following article, it can pay to try changing the process first. It might really be easier than changing the specification and selling the customer on the change.

This part of the series is planned to assist in determining both the natural tolerance and the acceptability of the product for each activity. The cases not covered in detail in the previous sections will be discussed.

Chart For Defects, Not Defectives: A defective is a part that in one or more ways exceeds an allowable limit. A *p* chart carries per cent defective results. Each way in which the part does not conform is a defect. The *c* chart shows the number of defects in subgroups of fixed size. Usually the subgroup or sample is one unit, an assembly for example, or a foot of wire, or a plate of glass of a given area. The sample can also be a group of units of the same size. But it is important that the *chance* for defects to occur in each successive sample be equal. Also, as listed in TABLE 4, the mathematics of the *c* chart apply when the opportunity for defects to occur is great but only a relatively few do happen.

Accident statistics in any plant can be plotted on a *c* chart. With many machines and operators that work many seconds every day, there are virtually an infinite number of man-seconds during any one of which someone can get tangled up with the machinery. But actual experience may be something like an average of three fairly serious accidents per month. Other examples are the number of defective soldered joints in an electrical assembly, the number of pinholes on the surface of a treated part, the number of flaws in a rug or bolt of cloth, or the number of holes in the sheet metal work of a large assembly that required oversize rivets.

From the chart in *Fig.* 38 the position of the control limits for a *c* chart can be found. First, the number of defects found on each of ten or more successive subgroups is recorded. These are averaged and the results entered in the bottom horizontal scale of the graph. On the vertical scale are the upper and lower limits. These boundaries have been drawn to come always in between digits. The step arrangement figured into the chart gives limits that are clear for each future subgroup result. They answer definitely whether the process is or is not remaining in statistical control. Provided no change in inspection standards has occurred, a point below the lower control limit indicates a real improvement to the process has taken place. A point beyond the upper control limit means the process has become significantly worse—some corrective action should be initiated immediately.

Table 4—Basic Statistical Tools and Area of Use

Possible Check	Confirms	Process Control	Accept or Reject
Measurements	Product variation is stable in its dispersion about a fixed setting	$\overline{X}$ and R or sum and range chart	Lot Plot
Count bad items from good	Likelihood of producing a bad item is very close to constant	*p* chart	Attribute sampling
Count the bad spots per unit or group of product	Great room for defects but relatively few appear, and chance of number occurring is virtually constant	*c* chart	Attribute sampling

Table 5—Natural Machine Tolerances

(inches)

Machine Type	Machine No.	Natural Tolerance	Drawing Specifications
External Grinders			
..Univ.	3A-305	0.00048	4.288/4.289 Dia. of groove
..Plain	3A-226	0.00634	0.165/0.180 face step
..Plain	3A-410	0.0007	5.875—0.001 OD boss
..Plain	4050	0.00094	4.4999 + 0.000—0.0013 diam. sm. bear.
..Plain	4050	0.00094	7.1873 + 0.000—0.001 diam. lg. bear.
Internal Grinders			
	477	0.00048	3.877/3.875 ID bore
	477	0.00091	8.5007 ±0.0005 ID lg. bear.
	490	0.00077	5.3757 ±0.0005 ID sm. bear.
	490	0.00173	7.599 ±0.001 ID sm. bear.
..single-lobe	946	0.00128	1.381/1.393 width of track
..4-lobe	536	0.0084	1.631/1.643 width of track
Lathes and Turret Lathes			
	270	0.0024	8.675/8.680 OD of groove
	4024	0.012	8.235/8.250 OD
	402	0.0065	11.932/11.912 groove diam
	402	0.0028	9.165/9.135 bore diam
Miscellaneous Machines			
..Drillpress.	5050	0.01559	0.302-.322 of tapped hole
..Drillpress.	882	0.0032	2.335-2.305 spot face diam
..Drillpress.	468	0.001	0.635-0.625 dia. bolt hole
..Thread Miller	633	0.006	11.829/11.817 pitch diam
..Thread Miller	504	0.0031	10.4545/10.4425 pitch diam

The control limits are so placed that sample values from an unchanged process will reach one of them by chance only 1.3 times per thousand cases. *Fig.* 12 of Part 2 illustrated some typical *c* charts. In all these applications the area of opportunity for a defect to occur must be constant from point to point. Inspection findings on electronic assemblies should never be plotted on the same chart if those sets are of different size or internal arrangement, nor the number of "squawks" found in final inspection of bombers with those in fighter planes.

A Valuable Chart for Certain Dilemmas: It has been suggested that designers dimension for measurements by variables. This permits the use of variables-control charts, Reset-Run cards, and Lot Plots—all powerful statistical tools. But sometimes a design will simply not lend itself to the easy use of such variable measurements, go and not-go methods being the only practical ones for certain requirements.

Quality control men may be faced with a dilemma of a different kind, but one that will succumb to the following solution. Using an attribute control chart for per cent defectives, because the process runs at a low average *p*, it may be found that a rather large sample size is needed to have a chart of useful sensitivity. *Fig.* 39 is a special type of control chart for the number of defective pieces found in successive samples. Quality control men would call it a combination narrow-limit-gage and *np* chart. It artificially increases the per cent defective of a distribution by setting fixed-limit gages in from the specification limits. The number of pieces found to exceed the not-go and go inner-limit gages are entered as a pair of X's for each sample. Only when one of the X's crosses a control limit or when the sum of their numerical positions exceeds a limit, need some action be taken to correct the process. The sample size for the chart is conveniently fixed at ten items.

Steps in preparing the chart are:

1. Find the standard deviation of the process to figure how far in from the specification limit to set the gages. At the start, make some variable measurements even though they may be rather costly. Fill in a preliminary control chart of at least ten subgroups as described in Part 3. The standard deviation, σ, comes from dividing the average range by the constant, d_2, listed against sample size, n, in TABLE 6.
2. For a fixed "per cent defective" of 11 per cent move in 1.8 σ from the 3.0 σ points at the tails of the distribution of the individual values. This distance can be read from *Fig.* 5 of Part 1 of this series. The reason for picking 11 per cent shows up in *Fig.* 18 of Part 3, which indicates that an 11 per cent defective population will only slightly more than one times per thousand produce purely by chance a sample that will be 50 per cent defective (the upper control limit for a *p* chart). That means five pieces failing a gage out of a sample of ten will be the most allowed.
3. Again using *Fig.* 5 find the number of σ that the 3 σ point can be permitted beyond the specification limit. Suppose the allowable average per cent defective, is 2 per cent. From the chart, 2.05 σ from the average or middle of a normal distribution reaches a point where the area of the remaining tail is 2 per cent. Subtracting this 2.05 from the 3.0, gives 0.95 σ as the distance between 3 σ and the specification limit. If there were an objection to almost any per cent defective beyond the specification limit, however, the distance would naturally be zero.
4. Therefore, for 2 per cent, the gage is set in from the specification limit an amount equal to $1.8 - 0.95$ or 0.85 σ. If an average per cent defective approximately zero is allowed, this gage should be set in from the specification an amount equal to the full 1.8 σ. From one limit a go gage is set, and from the other a not-go gage.
5. Succeeding results are entered on a chart such as *Fig.* 39. Control limits will always be set at five pieces found beyond either inner-limit gage. The example illustrates first a clear shift in the process setting toward the not-go side so the tool requires resetting.
6. A subsequent point also falls beyond the not-go control limit, but this time "defective" pieces were also found in the same sample on the go side. This case calls out an increase in dispersion as compared to that when the standard deviation of the process was determined from the average range. Hence, this rule: Combined total number of pieces beyond both go and not-go inner-limit gages is six. The last two subgroups on the chart exceed this maximum, clearly showing that the tool either had gone dull or some other things had happened to prevent this process from holding its original dispersion. *Fig.* 18 gives the limit of six pieces. An 11 per cent average per cent defective for each tail amounts to a 22 per cent defective process. Its upper control limit is 65 per cent. Seven or more pieces out of ten are therefore out of control.

Table 6—Control Limit Constants

n	d_2	D_4	D_3
2	1.128	3.268	0
3	1.693	2.574	0
4	2.059	2.282	0
5	2.326	2.114	0
6	2.534	2.004	0
7	2.704	1.924	.076
8	2.847	1.864	.136
9	2.970	1.816	.184
10	3.078	1.777	.223
11	3.173	1.744	.256
12	3.258	1.717	.284
13	3.336	1.692	.308
14	3.407	1.671	.329
15	3.422	1.652	.348

When The Test Destroys The Material: The foregoing technique as well as this one for destructive testing depend for their success upon a relatively constant standard deviation. The former plan gave control with attribute methods that were almost as sensitive as those by variables and with only a small increase in the sample size. Here, however, the test must be economical since the inspected part can never be used. So, sampling inspection must be by variables.

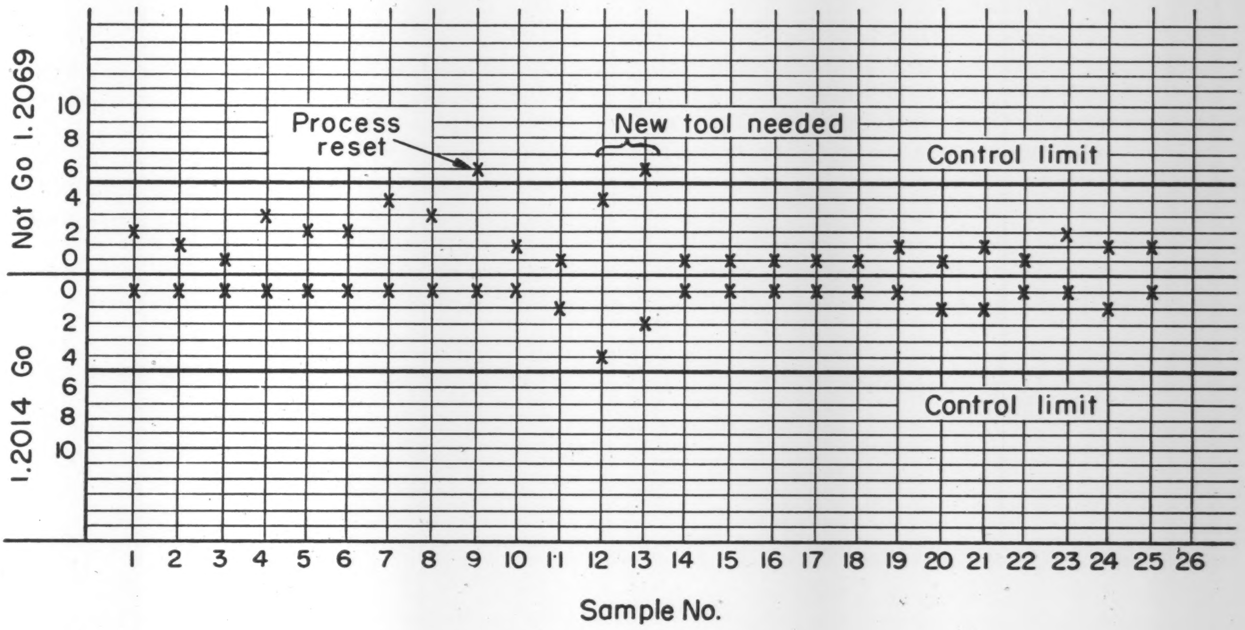
This plan results in the smallest possible sample to fit any chosen levels of the two types of risks that are part of every sampling plan. One is the risk of rejecting good lots and the other of accepting bad ones. The first called the producer's risk is usually taken as 5 per cent, or one time in 20. The latter, the consumer's risk, normally is 10 per cent, or one time in 10. At these levels of assurance the sample size, n, required is:

$$n = \left(\frac{2.93}{T_p - T_q}\right)^2 \qquad (1)$$

The subscripts p and q stand for per cent defective values, p being some low per cent defective or a value that is considered good quality (material that there would be no hesitation in accepting); while q is the per cent defective defined as poor quality, which would not be accepted very often. The T stands for a number of standard deviations under a normal curve. It represents the distance out from the average value to a point where the area of the remaining tail would be equal to, in one case p, and in the other case q, per cent defective. *Fig.* 5 (Part 1) has the number of standard deviations plotted against tail areas.

In addition to the sample size, a limiting value L for the average of the measurements found in the

Fig. 39—Chart for number of "defectives." Sensitivity is nearly equal to that of X and R chart



This chart was figured for this example: Spec. 1.200 to 1.210 inches; $\overline{R}$ from 10 samples of 3 each $= \Sigma R/N = 0.029/10 = 0.0029$; $\sigma = \overline{R}/d_2 = 0.0029/1.69 = 0.0017$; to maintain $\overline{p}$ of 2 per cent at the 1.200 inches spec. set inner gage at $1.200 + 0.85(0.0017) = 1.2014$ inches; to hold $\overline{p}$ of zero at the 1.210 inches limit set gage at $1.210 - 1.8(0.0017) = 1.2069$ inches. Finally checking ability of process to meet these $\overline{p}$'s: $6\sigma = 6(0.0017) = 0.0102$ inches, this exceeds spec. by 0.0002 or $0.0002/0.0017 = 0.85\sigma$. *Fig.* 5 indicates process can be set to hold minimum per cent defective of 1.5%.

sample is needed. This figure depends upon the standard deviation of the characteristic of the material being measured. Its value is

$$L = S \pm \sigma\left(T_p - \frac{1.65}{\sqrt{n}}\right) \quad \text{.....................} \quad (2)$$

The plus sign is used when S is a minimum specification value and the minus sign is used when S is the maximum allowable figure.

To put this plan in operation select two per cent defectives, p and q, that correspond to the two types of risks. Find the number of standard deviations, T_p and T_q, from *Fig.* 5 and the sample size, n, from Equation 1. From Equation 2, determine from the standard deviation of the sample data the highest and lowest limits for the average of the sample.

In working to the plan, observe three standard steps. Take the sample strictly at random, preferably with the aid of a table of random numbers. Make the measurements as accurately as possible, and record all readings. To get a good estimate of the standard deviation, several samples are needed so that their ranges can be averaged. But, although it is not desirable it will be necessary to take the range from the first sample and consider it as an average range until better data from other sampled lots can be used. The conversion of average range, $\overline{R}$, to standard deviation is made by dividing by the factor d_2 from TABLE 6.

$$\sigma = \frac{\overline{R}}{d_2} \quad \text{.....................................} \quad (3)$$

The estimated standard deviation is used in Equation 2 for L. As additional samples are taken R can be adjusted and a range chart can be maintained as a check on the relative dispersion from lot to lot. This chart will have upper and lower control limits, for ranges, found by multiplying the average range by the factors D_4 and D_3 listed in the table,

$$\text{Range } CL = D_4\overline{R} \qquad \text{Range } CL = D_3\overline{R}$$

Whenever the average of the sample falls within the L limits and the range lies within its control limits, then the lot is acceptable.

When the average exceeds one or the other of the limits L, the lot is rejected. The disposition of material can be scrap. But, if the test is not too expensive, an additional sample can be taken. Make up a total sample of 50 so that, with a Lot Plot, the true per cent defective of the lot can be estimated accurately as well as the conditions of the worst *piece* to be expected.

If seven consecutive sample ranges all come above or all below the average range for those samples, the control limits for ranges should be recalculated. Use only the average range from the seven values. This will change σ and the L's should then be refigured.

The range of any one sample exceeding either one of its control limits is also significant. The dispersion of that sample is clearly not just a chance value from a lot with a standard deviation corresponding to the average range of the chart. A new σ should be calculated and new limits, L, just for that "dissenting" sample. The new limits should be used for later lots until it is clear that either a new situation prevails or the extremely high or low range value was a stray. In the former case the new limits should be continued, perhaps adjusted some from the additional data; in the latter the old limits should be brought back into use.

For typical measures of defectiveness that could be successfully used for this destructive sampling plan, consider p as 0.1 per cent and q as 2.0 per cent. One is our opinion of perfectly acceptable material and the other stands for lots that should be rejected most of the time. With these values the sample size comes out to be eight pieces. The positions of the limits L will, of course, depend both upon the specification limits and the standard deviation found from actual measurements. T_p will be 3.09 for substitution in the equation.

Continuous Sampling by Attributes: Some processes are the conveyor-belt type. They run at such a rate that formation of good-sized lots for standard sampling is impractical. Here the Continuous Lot Plot described in Part 4 should be used whenever measurements on the resulting product can be made. But when variables inspection is impossible or impractical, use a simple plan developed by Harold F. Dodge. With *Fig.* 40* and the following procedure, a valuable plan is at your disposal.

Select a value of average outgoing quality limit (AOQL in percentage) that is desired in the long run. On the proper curve on the chart, a choice of any pair of co-ordinates that give a point on this curve can be made. For every f value, percentage of product sampled, there is an i value, consecutive number of units to be checked 100 per cent. At the outset inspect i units produced in a row. If all come within acceptable limits, continue sampling at the rate f per cent of the individual pieces coming from the flow of product. Selection must be made in a way to assure a random sample. If a sample unit is found defective, return to 100 per cent inspection of all succeeding units until i number of units are found acceptable, so it is safe to return to sampling. Correct any defective units found or replace them with good units. Then, in the long run, the AOQL value will not be exceeded.

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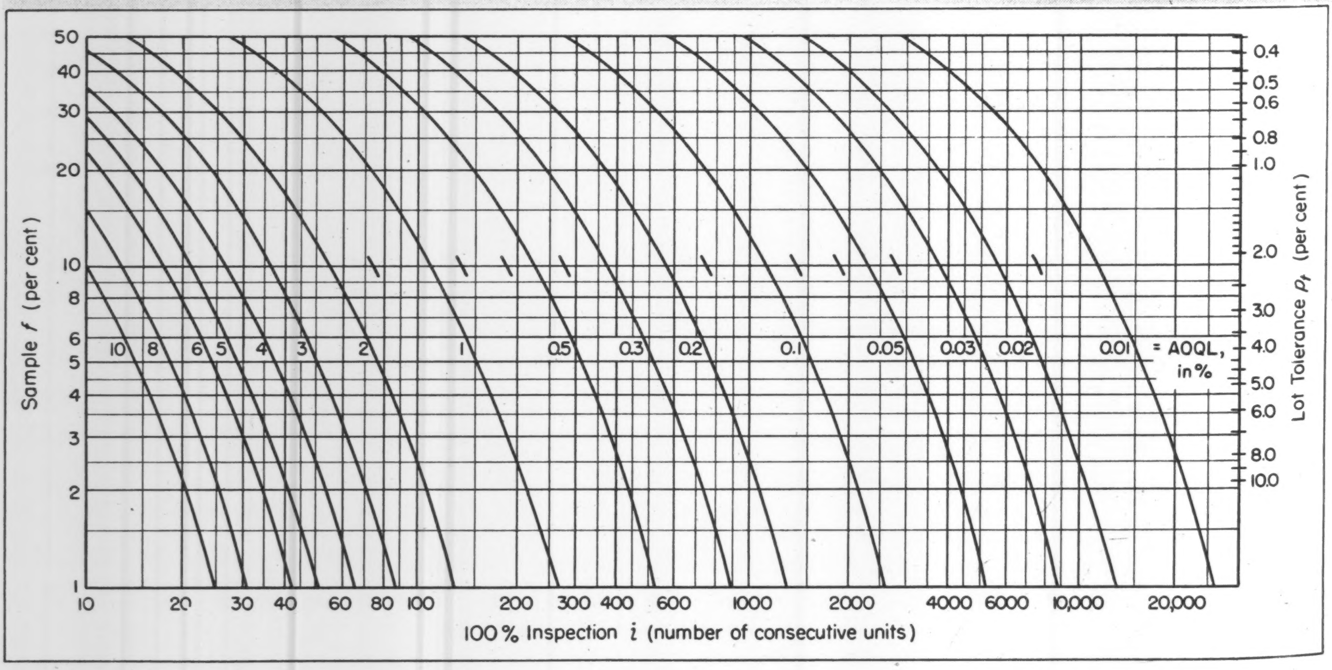
*Reprinted by special permission of Mr. Dodge and The Institute of Mathematical Statistics from "A Sampling Inspection Plan For Continuous Production", H. F. Dodge, *The Annals of Mathematical Statistics*, December, 1943.

Fig. 40—Chart for use when variables inspection is impossible or impractical. Choice can be made of any sample, using go and not-go gaging, or similar decisions, for continuous production. Value of per cent defective $= p_t$ in a consecutive run of $N = 1000$ units for which the probability of acceptance, P_a, is 0.10 for a sample size of f per cent



For every value another number on the right-hand side of the chart labelled p_t, or Lot Tolerance, is found. This relative measure helps in picking the particular $f - i$ combination desired. The lot tolerance in a sampling plan is that lot per cent defective which, if it occurs, will produce a sample that will be rejected 90 per cent of the time (or accepted 10 per cent of the time). In order to give this value meaning, Mr. Dodge elected to consider each production run of 1000 items as a lot to which this value of lot tolerance would apply.

The Designer Can Classify Defects: By taking advantage of the best statistical quality control techniques, better design work will certainly result. Also, by these means the designer will understand better what his drawings will mean to a modern shop.

A problem arises in exercising the inspection function of confirming or denying that adequate quality has been built into the product. Someone has to decide the risk levels to be used. So inspectors usually have the job of classifying defects. Several of the Government Services have recommended the use of critical, major, and minor as appropriate categories. Very tight or strict risk levels tie in to the critical items, while those characteristics that seem of major or even minor importance will be able to be checked at progressively more liberal risk levels.

Since these Government recommendations primarily aim at attribute sampling plans, there is a basic quarrel with these classifications. In go and not-go type of inspection there is no indication of *how* defective a certain characteristic might be. There is only a measure of what percentage of parts in a series of lots might be defective. Consider a dimension on a part that might be deemed of minor importance. As the part departs from a specification limit more and more then the type of failure that might be encountered may move the dimension into the category of a major defect. As the extent of error on the part continues still further from the specification, it can become critical.

In Part 2 the fact was touched upon that each characteristic of a design has a main function. It has a structural or a mating (nonstructural) job to do. Also mentioned in passing was the fact that classifying specifications under these two general headings will assist in determining how to inspect the product. If the primary job of the characteristic is to assure a certain fit or clearance with a mating part, then it is not the variation of that characteristic on that part alone that counts. There is also a variation of the mating characteristic. How the two combine to give a resultant fit or clearance becomes the important thing. If we can predict something about the distribution of the fit or clearance, it is to this distribution that we should apply our desired risk levels.

The statistical laws of chance come into play with regard to how often a part at the extreme end of its tolerance will or will not come together by chance with a mating part at its extreme. Statistical advantage can be taken of the fact that two or more parts are involved in reaching a final result. When the dimension has a structural main job, this advantage disappears. Such dimensions must stand by themselves and receive no benefit from whatever any adjacent parts may have as values. So, tighter risk levels must be picked for such structural characteristics. The level should correspond to the *combination* risk level of the mating parts.

If designers will find their way clear to indicating on drawings those characteristics that are primarily of structural importance, the inspectors can automatically assign a tighter risk level to those figures. The lower level can then apply to all those not so indicated on the drawing. As far as the assemblies are concerned all the results can end up at the same tight risk level. Examples of such structural requirements mentioned were wall thicknesses, hardnesses of material, stress-relieving radii, etc.

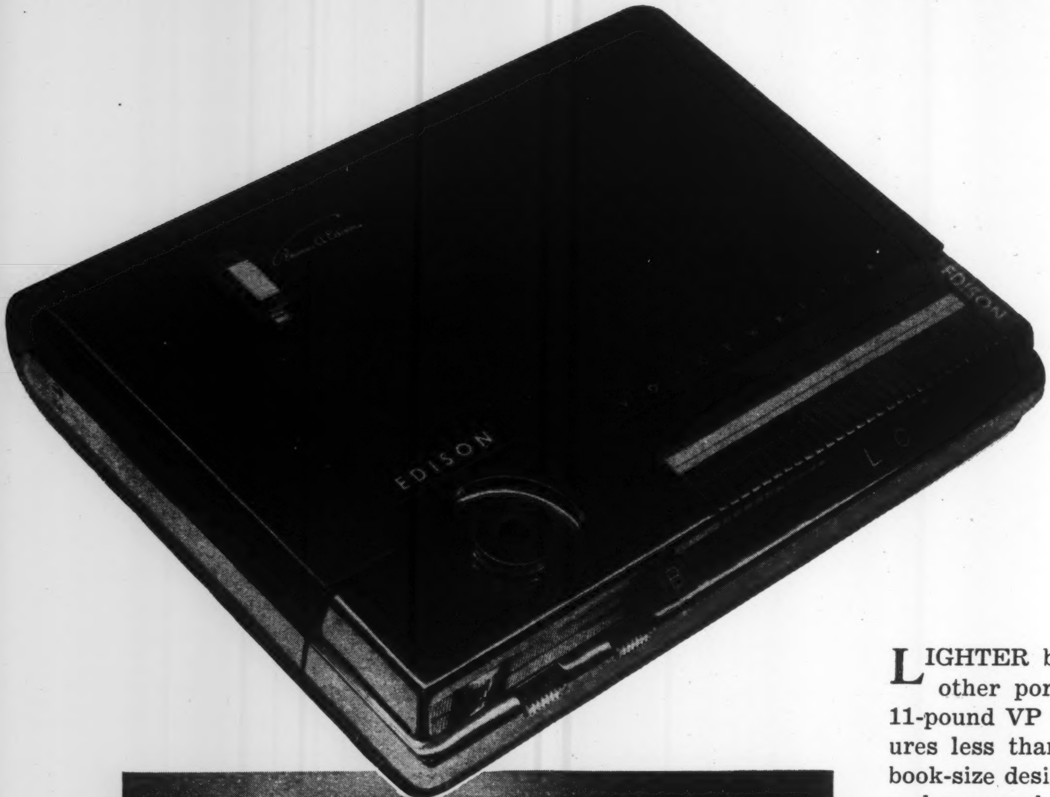
When using the Lot Plot plan it is not necessary to know whether the characteristic is primarily structural or mating. That plan has as its purpose the giving of as accurate a picture as is practical for the lot in question. Dispositions of lots found defective by Lot Plots, however, can be helped greatly by knowing how the designer classified the particular dimensions.

This classification becomes of great value to the inspector when attribute sampling must be used. In our plant a random sample of 75 pieces is used for mating characteristics, allowing no defects to have the lot accepted. For structural characteristics it is necessary to use a sample size of 300, still allowing no defects to consider the lot acceptable. In this way the risk of structural characteristics and of mating assembly fits is kept at about the same level, an AOQL of the order of magnitude of from 0.1 to 0.2 per cent. Other industries will find this classification scheme to be of value although sampling plans might well be picked with more liberal risk levels depending upon the requirements of the product.

Thermostats Protect Degreaser

WHEN GREASE-COATED or grimy parts are cleaned in vapor degreasers, the hot vapor generated by heating a reservoir of the solvent washes off the grease or grime which then collects as sludge in the bottom of the tank. Two problems arise in the operation of this type of unit; preventing the heavier-than-air solvent vapor from overflowing the top of the tank, and protecting the heater from burning out because of the insulating effects of the sludge accumulation.

Two thermostatic controls are combined in an ingenious system designed to answer both problems. One normally-closed Thermoswitch, manufactured by Fenwal Inc., is placed inside the tank at the "danger" level. This thermostat, set at 170 F, opens the heater circuit when the hot vapor reaches danger level, and closes when the vapor recedes. The other, set at 235 F, is installed next to the heaters, and cuts off power if the insulating action of the accumulated sludge causes the temperature to rise above the critical point.



CON

LIGHTER by approximately 25 per cent than other portable dictating machines, the new 11-pound VP Edison Voicewriter, top left, measures less than 2½ inches thick. This compact book-size design enables convenient portability—a long-sought feature in dictating machines. Most brief cases, bottom left, will accommodate the entire unit conveniently.

Recording medium of the new machine is a 7-inch coated vinylite plastic disk which provides 15 minutes recording time on each side. Disk positioning is automatic on insertion through a loading slot and subsequent closing of the cover. A turbine-type blower provides forced convection cooling for the drive motor and other electrical equipment within the case.

Power consumption of the VP transcriber is only 25 watts. This includes power required for an electronic normalizer which equalizes the recording level of strong or weak voices. Normal operating current is 115 v 60 cycle ac, although available converters enable operation on other currents including the 6-volt automotive system.

The combined microphone-speaker, below, contains the usual start and stop control for record-

MPORARY
DESIGN

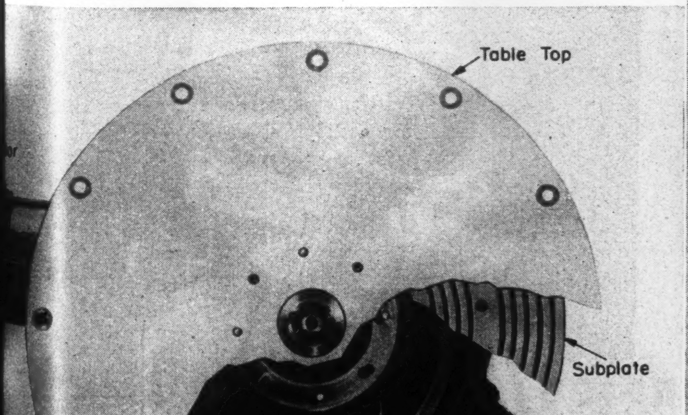
htweight Transcriber

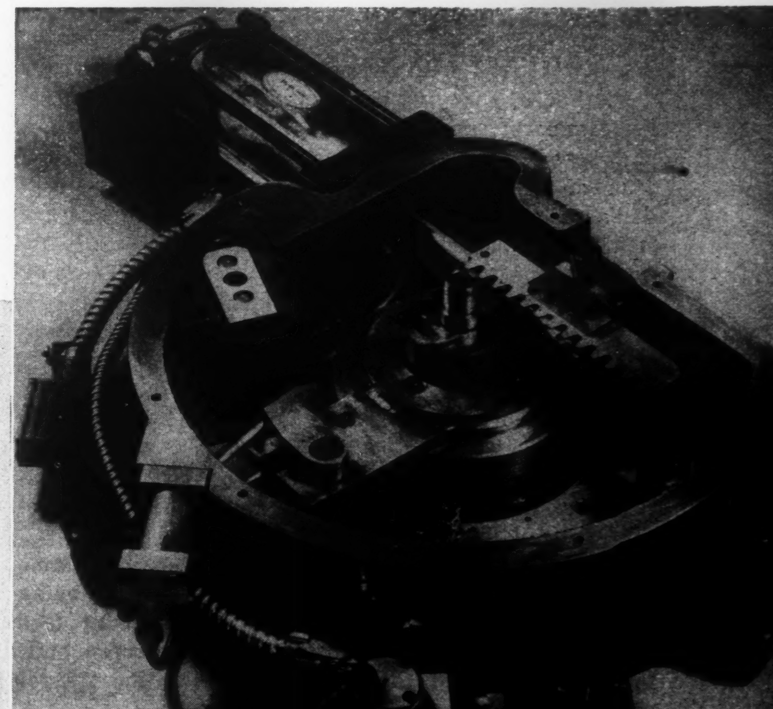
ing or playback. A single control dial sets the instrument for recording, affords complete playback, instant recall of the last few words transcribed and audio scanning of the entire disk. Keys are provided for automatic back-spacing, indication of transcription length, and indication of corrections. A special on-off power switch has a third position which locks the recording mechanism for safe transport.

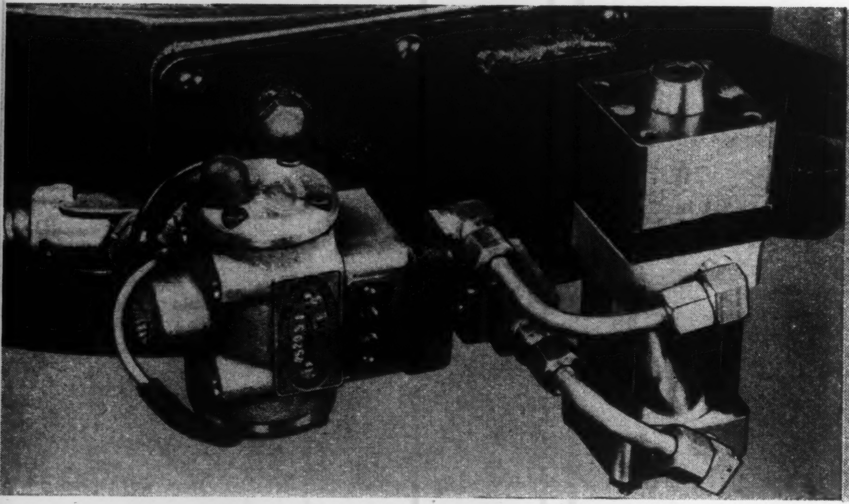
Styled by Carl Otto, the sleek new instrument is finished in gray beige and trimmed in polished aluminum. Two years of research and development at the Edison laboratories have gone into perfecting the lightweight machine designed for heavy-duty office as well as portable use.

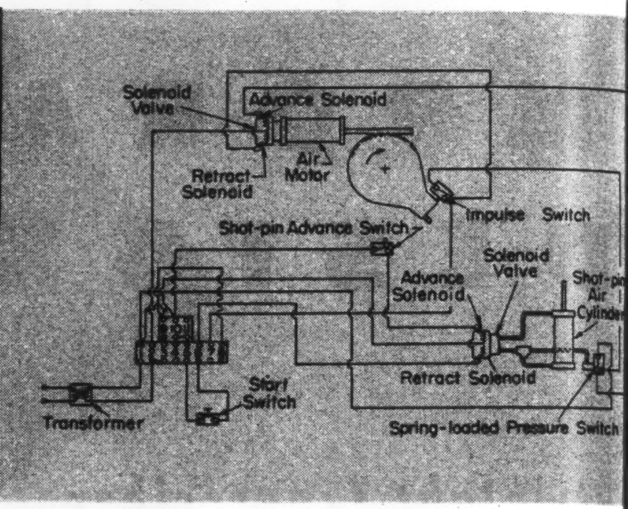
Electropneumatic Index Table

RAPID-FIRE indexing with repeat positioning accuracy of ± 0.001-inch is accomplished electropneumatically in the new Bellows rotary indexing table, below left. Straight-line motion of a piston-operated rack, below right, imparts rotary motion to the table through a gear quadrant and pawl arrangement which drives a ratchet wheel mounted on the underside of the table subplate. On the indexing stroke,









the pawl is held in engagement with the ratchet wheel through sliding engagement with an air-actuated curved and pivoted guide shoe.

Indexed positions are held by a tapered shot pin, top left. This air-operated pin engages hardened aligning bushings in the table top. During reset stroke of the indexing piston and rack, the curved guide shoe swings away to permit pawl disengagement.

Limit-switch and pressure-switch actuation of solenoid valves provides interlocking sequence control for automatic or manual operation of the table. Schematic diagram, top right, shows the circuit arrangement of the various elements for pushbutton indexing.

With the standard 18-hole 26-inch table top, the new model BRET-26 rotary table may be set to index 6, 9 or 18 stations. Position of the pad-mounted impulse limit switch inside the base determines the angular movement by controlling reset travel of the main actuating piston.

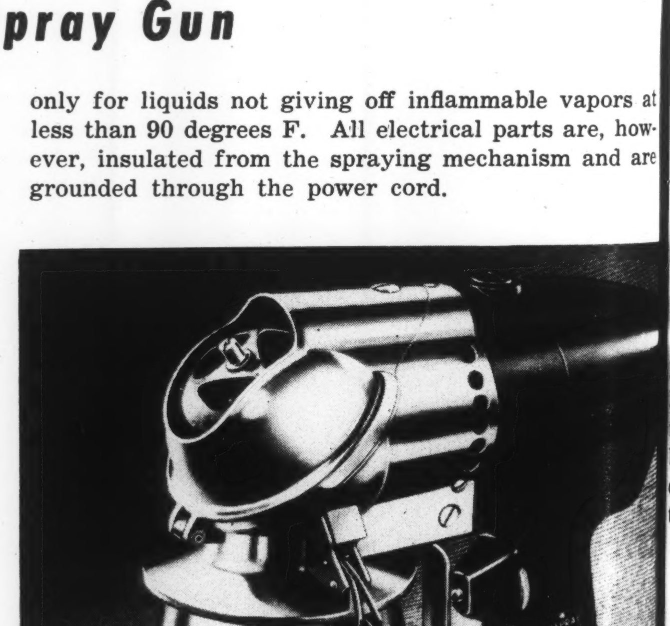
Airless Spray Gun

IN CONTRAST with the conventional compressed air method of spraying paints and other liquid finishes, the Egaspray gun, right, operates essentially as a high-speed electrically driven centrifuge. The ball head of this gun atomizes and impels minute particles of paint onto work surfaces. In the absence of air turbulence, there is said to be practically no wasteful mist or rebound created. This enables using the gun unusually close to a work surface.

A 110-volt universal motor drives the rotating parts of the spray head. This motor also drives, through a miniature nylon-geared speed reducer, a fluid pump of the Archimedean screw type. Located inside the paint cannister, this pump runs continuously with motor operation and, when not discharging into the centrifuge, circulates the paint within the cannister to prevent settling or thickening.

Density of the spray is proportional to paint volume delivered to the head. This is controlled by varying the area of a trigger-opened gap in the paint feed tube. The feed gap is set by an adjusting screw built into the handle of the gun for limiting the trigger movement.

Using oil-base paints, the airless spray, built by EGA Developments Ltd., Staffordshire, England, will cover approximately 9 square feet in one minute. For the same area, but with water-soluble paints, from 70 to 90 seconds are required. Because of possible arcing at the motor brushes, the gun is recommended only for liquids not giving off inflammable vapors at less than 90 degrees F. All electrical parts are, however, insulated from the spraying mechanism and are grounded through the power cord.



CONTEMPORARY DESIGN

Rotary Knife Hose Cutter

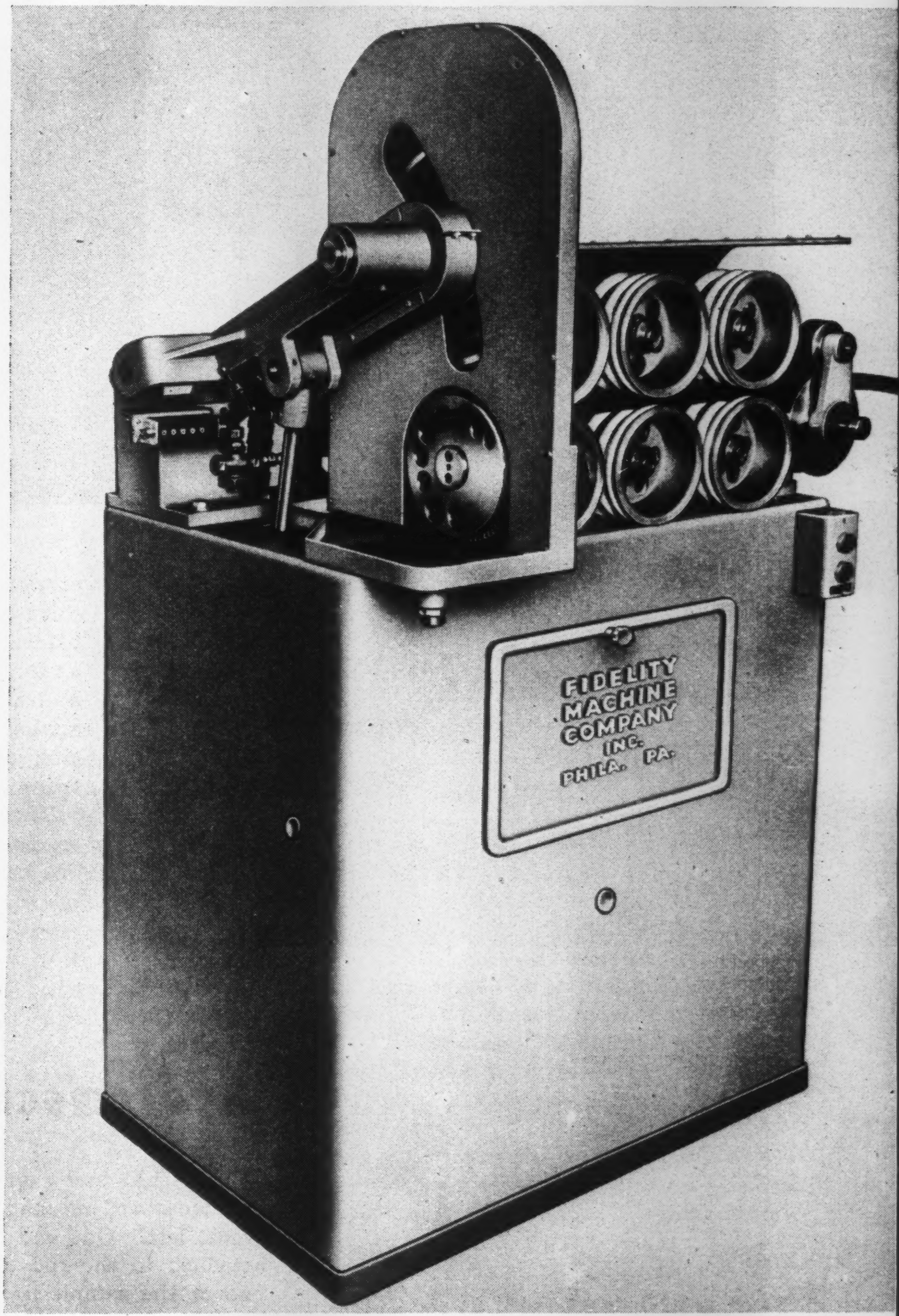
HIGH-SPEED automatic measuring, cutting and counting of hose sections ranging in length from one inch to twelve feet is accomplished by a newly designed machine, right, which utilizes a swinging rotary knife to sever through-fed stock.

Six geared feed rolls draw the hose into the machine and position it accurately for cut-off. These rolls are grooved to accommodate three ranges of hose diameters from ½-inch to 1¼ inches outside diameter. Top gang of the feed rolls is spring-loaded to provide traction for pulling the stock into the machine and passing it through a guide hole in a stationary supporting disk. This disk, or dial, is geared to a control knob by which the various size guide holes may be indexed into alignment with the correct feed roll grooving for a given diameter hose.

A measuring control stops the hose feed according to predetermined adjustment. Simultaneously, the cutter spindle arm is pulled downward to sever the hose. Just before the rotating cutter touches the hose, a fluid jet system lubricates both the hose and the cutter. Number of pieces cut are totaled by a mechanical counter actuated by the swinging arm.

A two-horsepower motor mounted below the fulcrum of the swinging arm drives the high-speed cutter spindle. The alloy steel rotary cutter is designed for squarely cutting knitted, wrapped, or braided plastic or rubber hose, including the variety which contains built-in stranded grounding wire for electrical purposes.

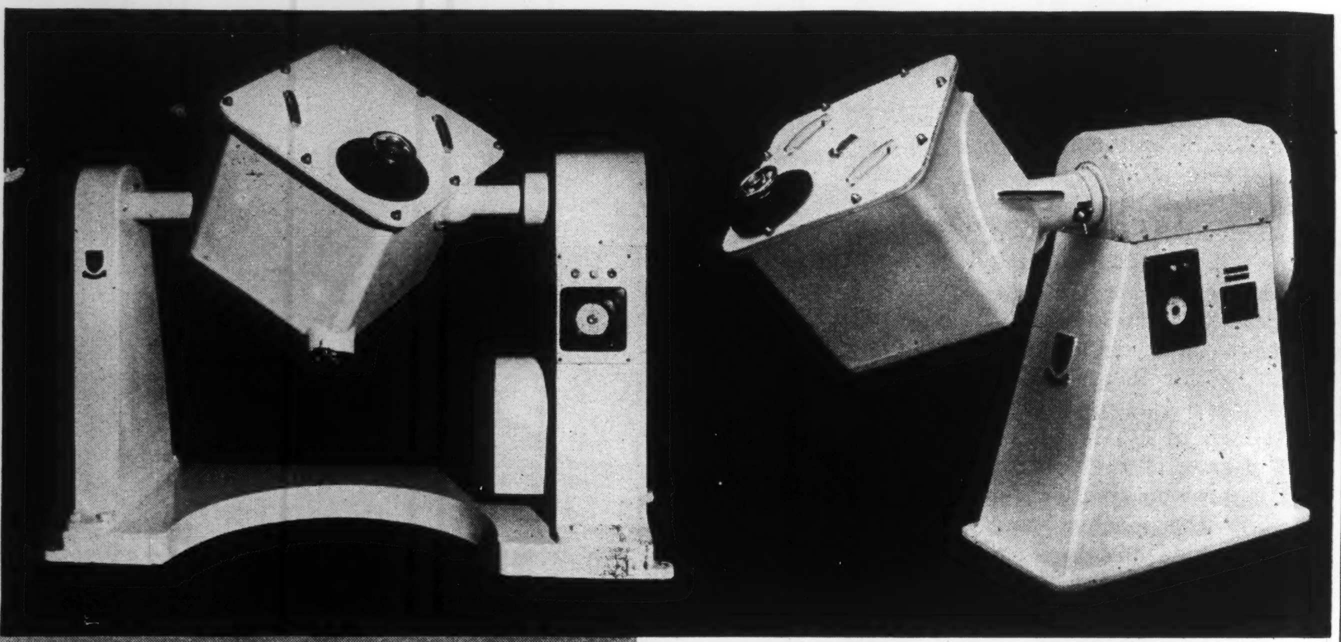
This new machine, built by the Fidelity Machine Co., will cut up to 45 sections of hose per minute—a production rate equal to that of several operators cutting hose by conventional methods. Floor space required by the hose cutter is slightly less than two feet by three feet.

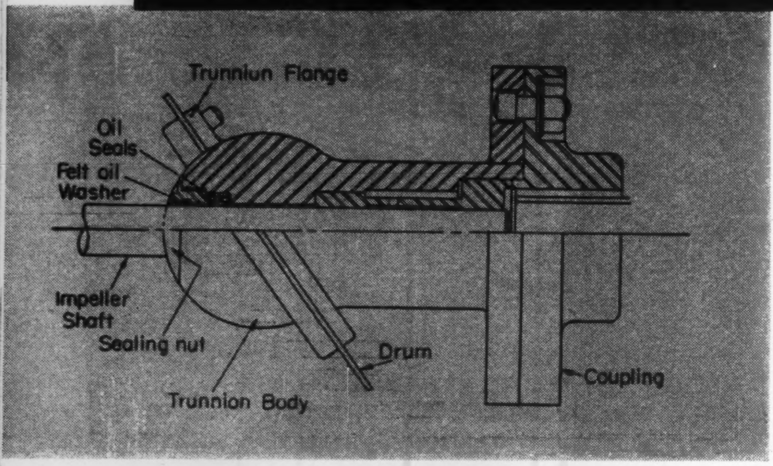


Ingredient Mixer

UNIFORM distribution of constituents, including those representing only minute percentages of the total mix, is effected in a new line of batch mixers, top next page. Cube-shaped containers of both models shown rotate at 10 rpm about body diagonals and thus prevent heavy particles of the mix from becoming concentrated in corners of containers.

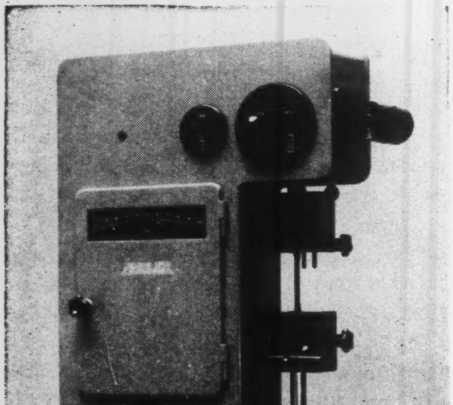
The cubicles are flange-mounted on ball-shaped trunnions, center left next page, through which an impeller shaft enters the mixing compartment. This shaft





carries a set of impeller blades which rotate at one third of trunnion speed for increasing agitation. These blades may be power-driven in either direction whereas the container rotates in one direction only. A triple seal arrangement protects the impeller shaft bearings against entry of materials being mixed. One felt seal ring and two lip-type cartridge seals are used in each trunnion.

These new mixers, built by Foster, Yates and Thomas, Ltd., Blackburn, England, range in capacity from 1¾ cu ft to 24¾ cu ft.



Hydromechanical Plastic Tester

TENSILE and compressive loads are applied hydraulically and measured mechanically in a new bench-type plastics testing machine, left. One end of the test sample is gripped in a guided head attached to the rod of a double-acting hydraulic piston. The other end of the sample is held in a similar head coupled to a scale beam having a pair of fulcrum holes. Also coupled to the beam is a mechanical linkage which reacts against a helical measuring spring.

Interchangeable indicating scales and springs provide for load ranges up to 10, 50, 100 and 150 kilograms with the fulcrum pin in the 1 to 1 ratio position, and for 100, 500, 1000 and 1500 kilograms in the 10 to 1 position.

Powered by a gear pump, the piston of the tester is speed-controlled, independent of pressure, between zero and twenty inches per minute through a conveniently located regulating valve. Made by A. J. Amsler and Co., Schaffhausen, Switzerland, this tester is reported to be accurate within one-half of one per cent in each load range between one-twentieth maximum load and the maximum.

By Sidney D. Millstone
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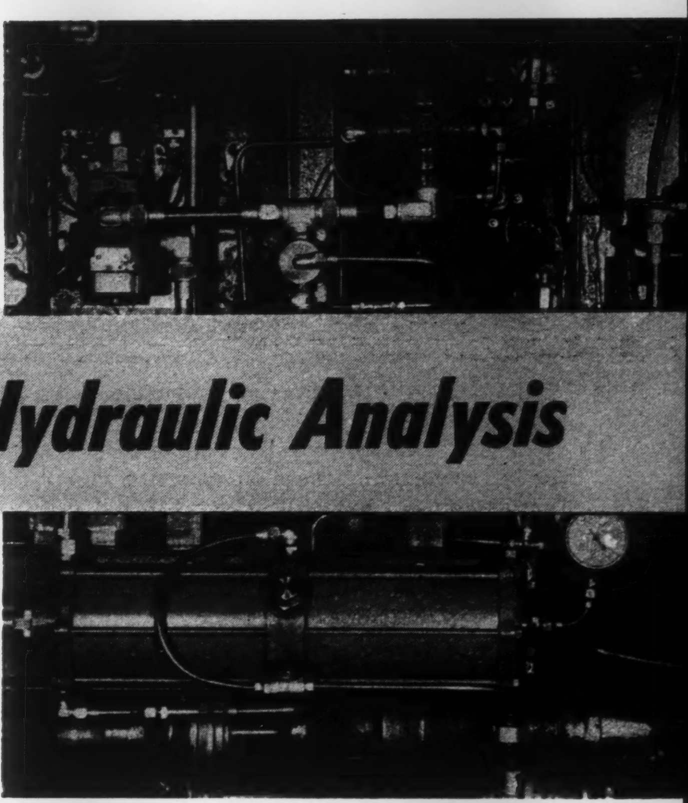
North American Aviation Inc.
Los Angeles, Calif.

Electric Analogies for Hydraulic Analysis

Part 1–System Components



INCREASING importance of high-performance hydraulic power-boost systems during recent years has led to the introduction of dynamic considerations in hydraulic component design. Usually, the power-boost system is only part of a more complete dynamic system which may include mechanical, electric, electronic, and thermal, as well as hydraulic equipment. However, calculating the response of the complete system first requires determination of the dynamic pressures and flow rates at specified critical points of the hydraulic system—a solution which may be greatly facilitated by electric analogies.

Although study of hydraulic system dynamics is possible without reference to electric analogies, there are several reasons why this approach is desirable. First, the high degree of development of electrodynamic circuit theory makes readily available, in electrical terms, a large part of the information necessary in the solution of hydraulic problems. Also, the electric analogy provides a single reference for writing both the hydraulic and mechanical system equations; the entire dynamic system may be represented as a single equivalent electric circuit. Finally the actual electric analogy can usually be constructed for the more complex systems and an experimental design study can be conducted without recourse to expensive and time-consuming hydraulic mock-ups.

The method presented in this series of articles for deriving electric analogies, as contrasted to other possible procedures,[1, 2] does not require a previous knowledge of the differential equations governing system behavior. Instead, it involves (1) derivation of a two-terminal electric network for each hydraulic system component and (2) replacement of the hydraulic component with its two-terminal analogy to create an overall circuit analogy for the complete hydraulic system. As a result, a set of hydraulic

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[1] References are tabulated at end of article.

EACH COMPONENT of a hydraulic system can readily be represented by a set of two-terminal electric network analogies. Analysis of the complete hydraulic circuit may then be performed with standard electric network equations. Moreover, since a complete system usually includes both electric and hydraulic components, the electric network equations provide a common basis of reference. In this three-part series, the analogies for the basic working components of hydraulic systems will be derived, the analogous characteristics of hydraulic tubing will be discussed, and application of analogy techniques to a hydraulic servomechanism will be demonstrated

component analogies can be tabulated and the electrically equivalent circuit quickly derived for any hydraulic system. Equations governing the system behavior may then be written and solved directly from the electric circuit with standard network analysis procedures.

In the development of electric analogies for high-performance hydraulic systems, typical components to be considered are:

1. Pumps
2. Orifices
3. Valves
4. Actuators or motors

Hydraulic tubing, usually employed as a medium for interconnecting these components, is omitted from this discussion, but will be treated separately in the second part of this series.

For the basic hydraulic component, *Fig. 1a,* fluid input flow rate is indicated by q_i, output flow rate by q_o. Corresponding pressures, P_i and P_o, conform to an arbitrary zero reference chosen for the system, usually fluid pressure at the reservoir. The two-terminal network analogy for the basic component is shown in *Fig. 1b;* E_i and E_o represent voltages to ground while i_i and i_o are the currents entering and leaving the network. By comparison, analogous quantities are (1) hydraulic pressure and electric voltage, and (2) fluid flow rate and electric current.

Hydraulic Pumps: The variable-volume type of hydraulic pump supplies a variable rate of fluid flow while maintaining a substantially constant output pressure. Input pressure at the reservoir, which is the lowest in the hydraulic system, is usually taken as the reference pressure, *Fig. 2a.*

For this type of pump, the electric analogy is a constant-voltage generator having a negative terminal which is the reference or ground terminal in the electric circuit, *Fig. 2b.*

If the pump is the constant-displacement type it delivers fluid at a constant rate and is therefore analogous to a generator delivering a constant current, *Fig. 2c.* Output pump pressure in this case varies in accordance with load requirements.

Orifice Characteristics: The basic orifice equation, which can be found in any standard hydraulics text[3], can be written as

$$\Delta P = K q^2 \qquad (1)$$

where ΔP is the pressure drop across the orifice, q is the flow rate, and K is a constant dependent on Reynolds' number and orifice geometry. Although Equation 1 was originally derived for steady flow rates only, this static pressure to flow relationship is also assumed for the dynamic orifice characteristic. The equation applies to an orifice with flow in either direction; however, orifice geometry may be somewhat different for opposite directions. Two constants (K) may be necessary to describe the orifice characteristics when flow changes direction.

An electrical relationship similar to Equation 1 can be written as

$$\Delta E = K i^2 \qquad (2)$$

where ΔE is a voltage drop and i is a current. Unfortunately, passive circuit elements with characteristics of Equation 2 are not generally manufactured. However, this square law characteristic can readily be achieved with diodes or other nonlinear function generating devices presently in use on analog computers.

Although a general passive circuit element does not exist in practice, it is desirable, nevertheless, to utilize a passive circuit element symbol for the orifice analogy. This two-terminal element can be derived by rewriting Equation 2 in the form,

$$\Delta E = (K i)\, i = R_n i \qquad (3)$$

where R_n represent a nonlinear resistor. Use of the resistor in the two-terminal network representation of the orifice simplifies construction of the complete circuit analogy as well as the writing of system equations. In addition, many dynamic applications require that only small deviations of pressure and flow about some operating point be studied and the resistor can frequently be considered as linear over this small range without appreciable inaccuracy. A schematic representation of this analogy is shown in *Fig.* 3.

Valve Characteristics: A valve is essentially an orifice or group of orifices with controllable characteristics. Therefore, its electric analogy will appear as a network of resistors. The hydraulic boost valve, *Fig. 4a,* is an important application. Flow from a pump enters the valve at the pressure port and returns to the reservoir through the return ports. When the valve spool is moved in the direction of the arrow, cylinder port *CP*-1 is opened to pressure permitting flow to the load. Cylinder port *CP*-2 is closed off to pressure but open to return for flow from the load. Since moving parts are involved, leakage across the

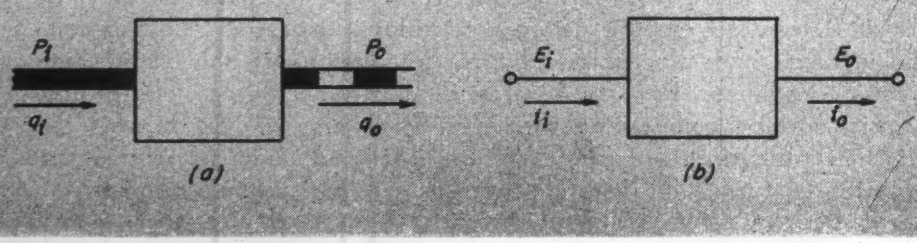

Fig. 1—Analogous quantities for basic hydraulic components, *a*, and corresponding two-terminal electric network, *b*, are pressure and voltage, fluid flow rate and current

return side of CP-1 and across the pressure side of CP-2 also influences valve behavior. With the spool moved up in the direction of the arrow, the main channel of flow occurs through the pressure side of CP-1 to the load and to the return side of CP-2 from the load. Leakage will occur across the return side of CP-1 and the pressure side of CP-2. When the spool is moved in the opposite direction, the main channel of flow is reversed and conditions at CP-1 and CP-2 are interchanged.

The electric analogy for this valve can be described by a bridge network arrangement, *Fig. 4b*. Each orifice has a characteristic equation similar to Equation 2 and can be written as

$$q = K' \sqrt{\Delta P}\,[f(x_v)] \qquad (4)$$

where $f(x_v)$ represents a function of the spool displacement and K' is a constant dependent upon Reynolds' number. The function, $f(x_v)$, is arbitrary within limits since the change in orifice geometry due to spool motion can be predetermined.

Equation 4 has a double nonlinear characteristic. Not only does it involve two generally nonlinear functions, it also requires that the product of these functions be determined. Circuits involving such characteristics are extremely difficult to solve analytically. Solution usually requires an analog computer. A passive network computer with nonlinear devices capable of reproducing these functions is presently in operation at the California Institute of Technology.[4] However, analytic solutions of these circuits are sometimes possible with the aid of linearizing approximations which will be discussed in more detail in Part 3 of this series.

ELECTRIC ANALOGIES

Hydraulic Actuators: A simple hydraulic actuator moving a mass-spring load is shown in *Fig.* 5. Although the mass and spring are mechanical elements rather than hydraulic, they nevertheless constitute an integral part of the actuator dynamics because they have a primary influence on input and output pressures and flow rates. This interdependence of mechanical and hydraulic components may be illustrated by writing Newton's Law for motion of the mass.

$$(P_i - P_o)\,A - K\,x_p = M\,a_p = M\,\frac{d^2x_p}{dt^2} \qquad (5)$$

where A is the effective piston area, M is the effective mass at the actuator, K is the effective spring rate, a_p is the piston acceleration, and x_p is the piston displacement from the equilibrium or reference position. Piston displacement is related to cylinder flow rate by

$$q_p = A\,\frac{dx_p}{dt} \qquad (6)$$

where q_p is the rate of flow of fluid volume moved by the actuator. In addition to q_p, there is an additional flow due to leakage between the piston and cylinder walls, which is considered proportional to the pressure drop across the piston. The defining equation for this flow rate, q_l, is

$$q_l = \frac{(P_i - P_o)}{R_l} \qquad (7)$$

where R_l is the effective piston-cylinder leakage re-

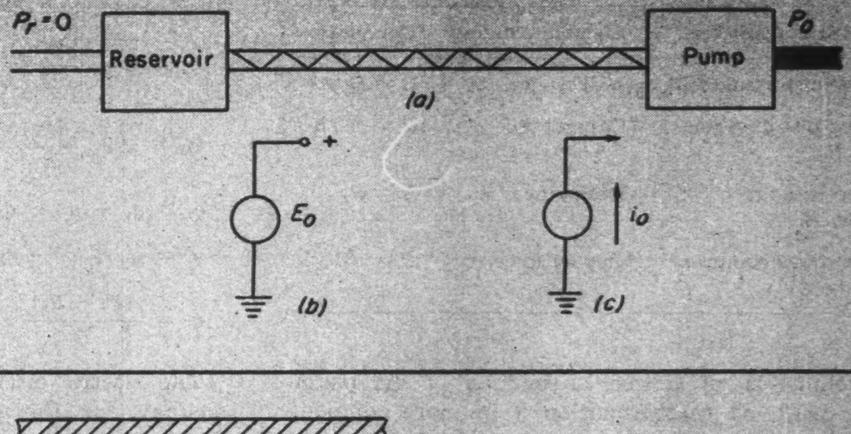

Fig. 2—Electric analogies for hydraulic pump, *a*, are constant-voltage generator, *b*, for variable-volume type and constant-current generator, *c*, for constant-displacement type

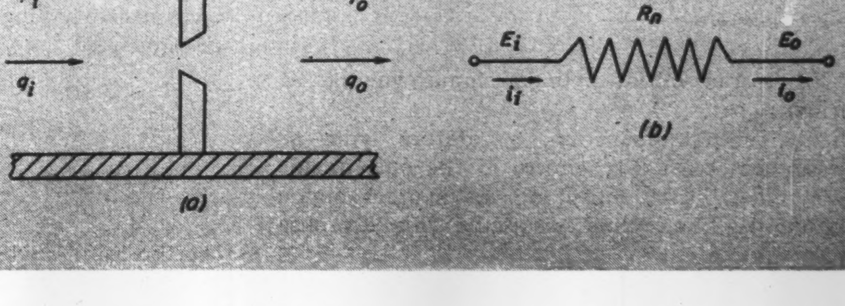

Fig. 3—Characteristics of orifice, *a*, are simulated in its electric analogy, *b*, by a nonlinear resistor

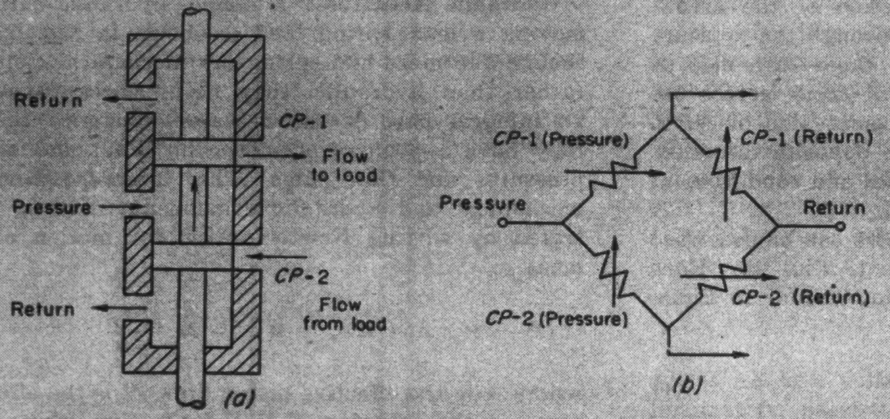

Fig. 4 — Hydraulic boost valve, *a*, which is essentially a group of controlled orifices, can be simulated electrically by a bridge network, *b*

sistance factor.

Thus, from Equations 6 and 7 the net internal actuator flow rate, q_n is

$$q_n = q_p + q_l \qquad (8)$$

Input flow rate to the actuator, q_i, differs from q_n because of compressibility effects on the fluid entering the cylinder. This decrease in flow rate, q_α, can be written as

$$q_i - q_n = q_\alpha = \beta V_i \frac{dP_i}{dt} \qquad (9)$$

where β is the fluid compressibility factor and V_i is the volume of fluid in the input side of the cylinder.

Table 1—Analogous Quantities for Hydraulic Actuator

Actuator Parameter	Electric Analogy	Correlation
Effective piston mass, M	Inductance, L	$L = M/A^2$
Effective piston spring rate, K	Capacitance, C	$C = A^2/K$
Cylinder leakage factor, R_l	Resistance, R	$R = R_l$
Cylinder fluid compressibility, βV	Capacitance, C	$C = \beta V$

This volume is, of course, a function of the piston displacement, so that Equation 9 in more complete form is

$$q_\alpha = \beta\,(V_n + A\,x_p)\,\frac{dP_i}{dt} \qquad (10)$$

where V_n is the initial cylinder input volume at equilibrium.

Similarly, output flow rate, q_o, differs from q_n because of compressibility effects in the output side of the cylinder. Assuming that the neutral piston position divides the cylinder equally, this decrease in flow rate, q_β, is

$$q_\beta = q_n - q_o = \beta\,V_o\,\frac{dP_o}{dt}$$

$$= \beta\,(V_n - A\,x_p)\,\frac{dP_o}{dt} \qquad (11)$$

where V_o is the volume of fluid on the output side of the cylinder. The equation of the electric analogy for the actuator can be derived from Equations 5 through 11. Integration of Equation 6 gives

$$x_p = \frac{1}{A}\int q_p\,dt \qquad (12)$$

Substituting Equation 12 into Equation 5, dividing by A and rearranging terms yield

$$P_i - P_o = \frac{M}{A^2}\,\frac{dq_p}{dt} + \frac{K}{A^2}\int q_p\,dt \qquad (13)$$

Other equations pertinent to the analogy are

$$q_\alpha = \beta\,V_i\,\frac{dP_i}{dt} \qquad (14)$$

$$q_\beta = \beta\,V_o\,\frac{dP_o}{dt} \qquad (15)$$

$$q_i = q_\alpha + q_p + q_l \qquad (16)$$

$$q_o = q_p + q_l - q_\beta \qquad (17)$$

$$q_l = \frac{(P_i - P_o)}{R_l} \qquad (18)$$

The electric circuit shown in *Fig.* 6 represents an analogy for the hydraulic actuator. This can be demonstrated by application of Kirchoff's laws to the branches of the network. Currents through the condensers having capacitance values of C_α and C_β are given by

$$i_\alpha = C_\alpha\,\frac{dE_i}{dt} \qquad (19)$$

$$i_\beta = C_\beta\,\frac{dE_o}{dt} \qquad (20)$$

At the input node, the current relation is

$$i_i = i_p + i_l + i_\alpha \qquad (21)$$

while at the output node it is

$$i_o = -i_\beta + i_p + i_l \qquad (22)$$

Current through the resistance branch of the parallel network is

$$i_l = \frac{E_i - E_o}{R_l} \qquad (23)$$

From Kirchoff's voltage law the relation for the series resonant circuit is

$$E_i - E_o = L\,\frac{di_p}{dt} + \frac{1}{C}\int i\,dt \qquad (24)$$

where L is inductance and C is capacitance of that branch.

Equations 19 through 23 are identical in form to the relations of Equations 14 through 18. The same identity in form also exists between Equations 13 and 24. Analogous quantities from the equations are listed in TABLE 1.

The condensers of capacitance C_α and C_β can usually be neglected for practical hydraulic systems. However, for pneumatic actuators or for actuators in systems with resonant frequencies above 25 cps these condensers assume importance. The capacitance values are functions of piston position,

$$C_\alpha = \beta\,(V_n + A\,x_p) \qquad (25)$$

$$C_\beta = \beta\,(V_n - A\,x_p) \qquad (26)$$

Therefore, the condensers are fundamentally nonlinear elements and cannot be handled by linear circuit theory techniques. Unless the circuits are studied with the aid of a nonlinear analog computer, the assumption must be made in the analysis that C_α and C_β are either negligible or have some constant value.

In the next part of this series the electric analogies for tubing in hydraulic circuits will be developed.

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3. H. O. Croft—*Thermodynamics, Fluid Flow, and Heat Transmission*, McGraw-Hill Book Co., New York, 1939.
4. G. D. McCann, C. E. Wilts, and B. Locanthi—"Application of the California Institute of Technology Electric Analogue Computer to Non-Linear Mechanics and Servomechanisms," *AIEE Transactions*, Vol. 68, 1949.

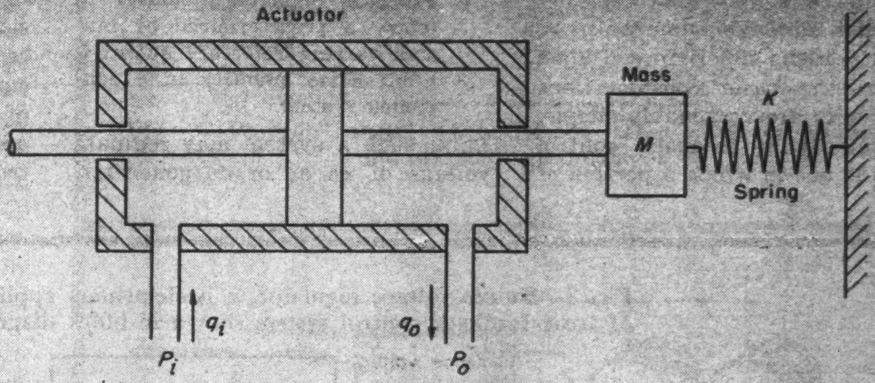

Fig. 5 — Mechanical mass and spring elements have primary influence on this simple hydraulic actuator and must be considered in performance analysis

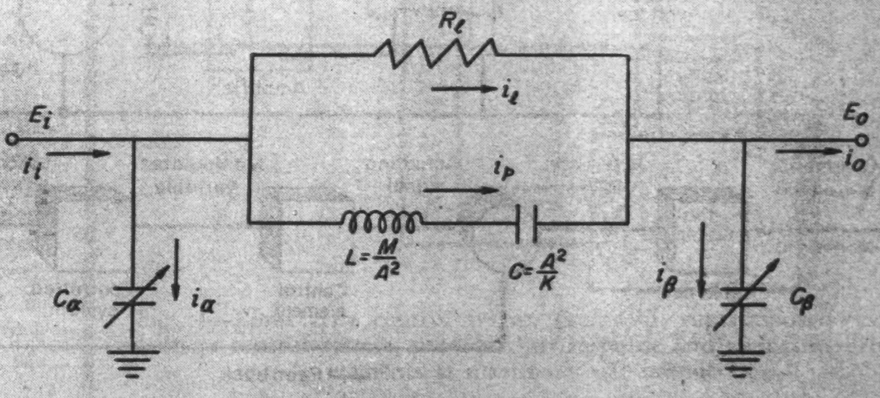

Fig. 6—Electric analogy for hydraulic actuator of Fig. 5 is described in this circuit diagram which utilizes a parallel branch network to simulate effects of mechanical elements

DESIGN ABSTRACTS

Feedback Control

. . . for precision automatic machine operation

By R. W. Moore
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Control Engineering Dept.
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FAST, precise, and automatic operation of many modern industrial processes is largely dependent upon feedback control systems. Recent developments in materials, devices and analytical methods that enable accurate predetermination of results have contributed to vast improvements in these controls. Although the finished systems often prove to be somewhat complex—sometimes employing one or more control systems superimposed upon another—the basic considerations and circuits are reasonably simple.

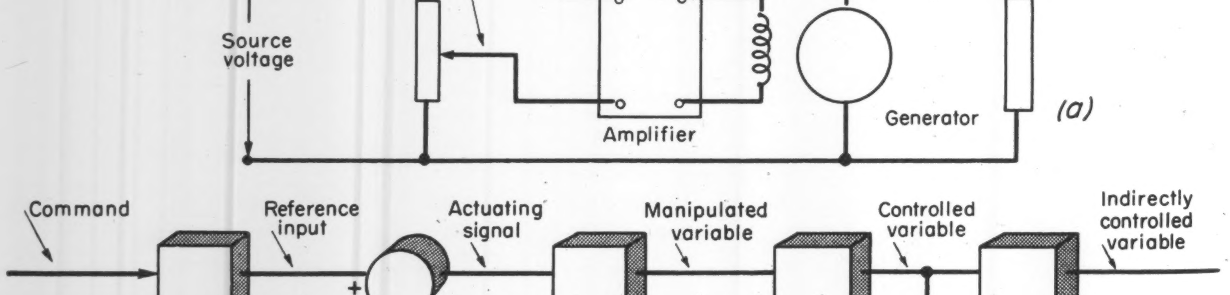
Essentially, a feedback control system is one in which a portion of the output of the controlled system is transmitted as a correcting signal back to the control, whereupon it is applied to correct the variable in question—whether speed, position, temperature, or other. More specifically, this type of system is used to

1. Hold some regulated quantity within close limits.
2. Force a regulated quantity to follow a predetermined or random varying reference quantity.
3. Limit some quantity in a controlled system.

Thus, such a system may regulate voltage of an ac or dc generator, torque or horsepower of a motor drive, speed of a mill drive, angular position of a shaft, space position of material in a machine, or temperature of a furnace.

Feedback control systems are, in general, applied to regulate or govern the flow of energy. Components that can be used are many and varied. But, irrespective of the components or the system considered, the fundamental advantages of the feedback control principle are the same and the methods of analysis are identical. These advantages are that (1) a controlled quantity can be forced, at a

Fig. 1—Simple voltage regulator, *a*, is elementary application of basic feedback control system shown in block diagram, *b*


Reference voltage
Field
Load
Source voltage
Amplifier
Generator
(a)
Command
Reference input
Actuating signal
Manipulated variable
Controlled variable
Indirectly controlled variable
+
−
Reference
Control element
Controlled system
Indirectly controlled system
(b)
Feed back

predetermined rate with predetermined accuracy, to follow a specified reference and (2) the controlled quantity, once a command is given, can be maintained within the desired limits of accuracy and corrections for disturbances will be made without necessity for human attention.

To secure these advantages, consideration must be given not only to the elements in the particular system to be designed, but also to the external elements supplying the system as well as to those supplied by the system. For example, if a mill drive is to be controlled, a determining factor is often whether the power system can supply the power the feedback control will force the drive to demand. Another prerequisite of control design is a thorough knowledge of the material being produced, or of the process, so that particular material or process characteristics may be compensated.

Elementary Feedback Control System: Performance of a feedback control system can more easily be understood by considering a basic system, such as the elementary voltage regulator shown schematically in *Fig.* 1 *a*. This consists of a generator whose voltage is being regulated, an amplfier and a reference voltage to which the generator voltage is compared. The amplifier can be a dc generator, a magnetic amplifier, or an electronic amplifier. The reference, which for this system is a voltage, is the standard to which the regulated quantity is compared.

If a difference exists between the reference voltage and the generator voltage, it is applied as the input of the amplifier and, in turn, produces a voltage to excite the field of the generator in such a direction as to minimize or eliminate the difference between regulated voltage and reference voltage.

This voltage-control system illustrates completely but simply the feedback control principle—using the difference between a reference and a controlled quantity to correct the controlled quantity. However, to explain this principle in full, a more complete analysis can be obtained from the block diagram of *Fig.* 1 *b*.

(*Continued on Page* 284)

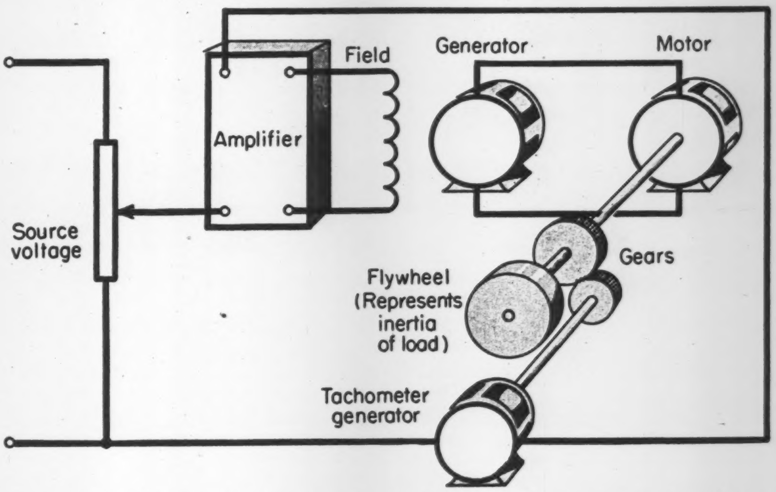

Field
Generator
Motor
Amplifier
Source voltage
Gears
Flywheel (Represents inertia of load)
Tachometer generator

Fig. 2—Speed control system is similar to voltage control system, *Fig.* 1 *a,* except that it includes elements to convert speed signals to voltages

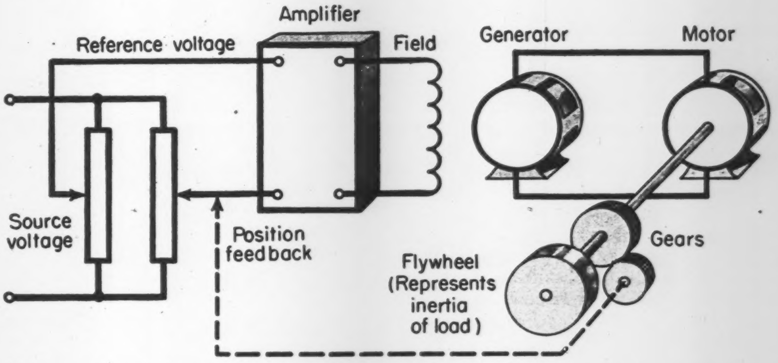

Amplifier
Reference voltage
Field
Generator
Motor
Source voltage
Position feedback
Gears
Flywheel (Represents inertia of load)

Fig. 3—Position control system is also often used for accurate and efficient speed control

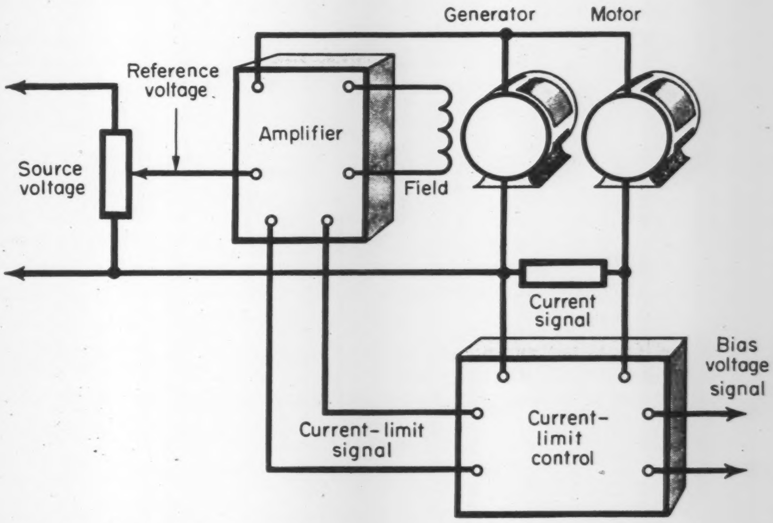

Generator
Motor
Reference voltage
Amplifier
Source voltage
Field
Current signal
Bias voltage signal
Current-limit signal
Current-limit control

Fig. 4—Limit type control system (current), superimposed on a voltage control system, provides fast response and maintains drive elements at maximum safe output

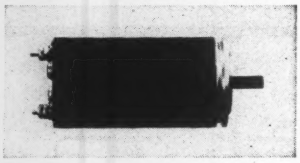
NEW PARTS AND MATERIALS

. . . presented in quick-reference data sheet form for the convenience of the reader. For additional information on these new developments, see Page 209

MINIATURE GENERATOR 1

. . . about the size of a flashlight battery

Globe Industries Inc., 125 *Sunrise Place, Dayton* 7, *Ohio*



Voltage output proportional to speed makes this small generator useful as a rate device in servo-systems.

Size: Approximately 2½ in. long, 1¼ in. diam.

Service: Generating dc voltage proportional to driven speed; maximum output, 2 v per 100 rpm, and 50 ma; load impedance must be at least 1000 ohm per v; "slot-lock" and friction have been kept low to produce low starting torques.

Design: Permanent magnet dc generator; plain or pinion type shafts furnished; screw type terminals or leads available; standard synchro type mounting or tapped holes for face mounting.

For more data circle MD 1, Page 209

CORROSION RESISTANT FINISH 2

. . . is easily applied

Parker Rust Proof Co., 2177 *E. Milwaukee Ave., Detroit* 11, *Mich.*

Ten times the corrosion resistance of conventional black finishes for iron and steel is claimed.

Designation: Parco Black.

Service: Protecting iron and steel surfaces from corrosion; applied by immersing parts in solution at 190-200 F for 15-30 min; solution is non-caustic, may be used in mild steel tanks although stainless steel tanks give longer life; may be safely used on threaded or machined parts; parts to be coated must be free of grease, rust and scale.

Properties: Black rustproof finish; phosphate coating with integral color.

For more data circle MD 2, Page 209

O-RINGS 3

. . . for use with synthetic lubricants

Precision Rubber Products Corp., 3110 *Oakridge Drive, Dayton* 7, *Ohio*

Developed for use in jet engines, these O-rings are not affected by dibasic ester type lubricants.

Designation: 142-70.

Size: All standard sizes.

Service: Sealing against synthetic lubricants of dibasic ester type covered by MIL-L-7808, MIL-O-6085, MIL-O-6387 and MIL-E-3278 at temperatures of −65 F to 350 or higher.

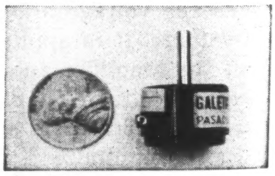
Design: O-ring seal of synthetic lubricant-resistant material; material meets MIL-R-7362 (USAF) for synthetic oil-resistant rubber products.

For more data circle MD 3, Page 209

MINIATURE POTENTIOMETER 4

. . . is only ¾-in. in diameter

Galetronics Inc., c/o Eastman-Pacific Co., 2320 *E.* 8*th St., Los Angeles* 21, *Calif.*



Standard resistance tolerance of plus or minus 5 percent places these potentiometers in the precision class.

Designation: RC.

Size: 0.75-in. diam, $\frac{11}{32}$-in. length; ⅛-in. diam shaft extends ½-in.

Service: Varying electrical resistance; max resistance from 7 to 320,000 ohm; rated 1 watt; linearity tolerance ±5%; electrical sweep to 358 deg; tests indicate probable min life of 1,000,000 sweeps.

Design: Miniature rotary potentiometer or rheostat; resistance elements may be of base or noble alloys; servo type mounting; available with ½-in. shaft extension at both ends if required.

For more data circle MD 4, Page 209

NEW PARTS

FREEWHEELING CLUTCHES 5

. . . for ⅛ to 4 in. diam shafts

Odin Corp., P.O. Box 6032, *Indianapolis* 20, *Ind.*

Precise construction minimizes friction when clutches are free wheeling.

Designation, Size and Service: Transmitting power in one direction of rotation only;

Model No.	Torque (lb-in.)	Shaft Diam (in.)	OD (in.)
125	2	0.125	¾
250	15	0.250	1⅛
500	122	0.500	2
1000	720	1.000	3¼
2000	6500	2.000	6
3000	17,500	3.000	9
4000	35,700	4.000	12

Design: Wedging-roller type free-wheeling clutch; housing of high grade hardened and ground steel; cast iron bearings; bores honed; available with gears integral with hub or housing; OD can be made to customers specifications; type D has housing extension with ID same as shaft size; type S designed for keyed connection to OD of housing; all bores slotted for square keys.

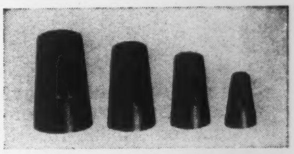
For more data circle MD 5, Page 209

WIRE CONNECTORS 7

. . . for solderless electrical connections

Van Cleef Bros. Inc., 7800 *Woodlawn Ave., Chicago* 19, *Ill.*

Made of phenolic material, these connectors prevent shorts and grounding.



Designation: DB.

Size and Service: Making quick solderless electrical connections; maximum rating 300 v; no tools are necessary for use—connectors screw on with fingers; connect AWG solid or stranded wires as follows and other combinations of smaller sizes;

Size	No. and Size of Wires	Size	No. and Size of Wires
DB-1	2 No. 16	DB-4	5 No. 16
	3 No. 18		6 No. 18
DB-3	2 No. 14	DB-6	3 No. 10
	4 No. 16		4 No. 12
	5 No. 18		6 No. 14
DB-4	2 No. 12		9 No. 16

Design: Internally threaded molded phenolic connectors; internal threads twist wires together automatically as connector is screwed onto wires.

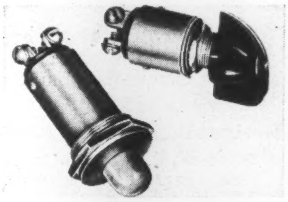
For more data circle MD 7, Page 209

SWITCHES 6

. . . are small and light

Hetherington Inc., Sharon Hill, Pa.

Cam-roller contactor design assures positive contact under adverse conditions, and has exceptionally effective wiping action.



Designation and Size: J 100—$2\frac{15}{32}$ in. long, mounts in $\frac{29}{32}$-in. diam hole, weighs 1 oz; R 1000—$1\frac{31}{32}$ in. long, mounts in ½-in diam hole, weighs 1 oz.

Service: For positively maintained contact; switch cannot be "teased off" contact; effective contact wiping action;

Load	Rated Current at 28 v dc (amp)	Rated Current at 115 v ac (amp)
Resistive	20	10
Inductive	15	10

Design: Single-pole double throw, push-button (J 100) or rotary (R 1000) actuation; cam-roller contactor of J 100 is actuated by escapement to maintain or break contact, total push-button travel is ¼-in.; R 1000 operated by 90 deg rotation of knob; both types have positive snap action and are housed in anodized aluminum cases.

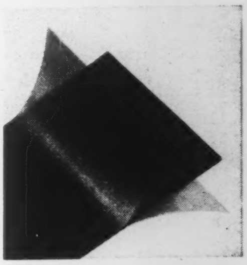
For more data circle MD 6, Page 209

ELECTRIC INSULATION 8

. . . easily folded and applied

Natvar Corp., Randolph Ave., Woodbridge, N. J.

This insulating material is claimed to be less expensive than mica combinations and other class B insulating materials.



Designation: Aboglas.

Form: Sheet.

Size: 36 x 36 in.; 0.025 to 0.027, or 0.050 to 0.054-in. thick.

Service: As class B electrical insulating material; resists heat, moisture, abrasive dust, oil and grease; 0.025 to 0.027-in. material has minimum dielectric breakdown strength of 12,000 v, 0.050 to 0.054-in.—19,000 v; can be easily folded and applied to irregular surfaces without heating yellow color.

Properties: Flexible sheet formed of 0.010 or 0.024-in. sheet of varnish-saturated asbestos paper and two layers of 0.007 or 0.012-in. sheets of varnished open-weave Fiberglas securely bonded together; is flexible, tough and non-flaking.

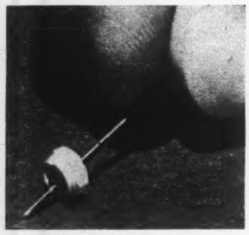
For more data circle MD 8, Page 209

NEW PARTS

MINIATURE STOPNUTS 9

. . . as small as 0.109-in. across flats

Elastic Stop Nut Corp. of America, 2330 Vauxhall Rd., Union, N. J.



Smallest nut previously made by this company measured 0.250-in. across flats.

Designation: Type 1660.

Size: Zero through 4 NF and NC threads.

Service: As locking fasteners; unaffected by vibration; may be used where a nut must be located at a certain position on a threaded member; maintains locking ability when reused.

Design: Self-locking nut of brass or aluminum; has nylon locking insert.

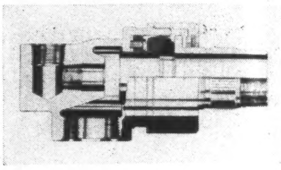
Applications: Optical instruments; servomechanisms; cameras; clocks.

For more data circle MD 9, Page 209

REVOLVING JOINTS 11

. . . withstand 250 psi steam pressure

Rotherm Engineering Co., 4911 W. Irving Park Rd., Chicago 41, Ill.



Self-aligning, these joints may be used with rigid piping.

Designation: Type YX.

Size: ½, ¾, 1¼, 1½ and 2 pipe sizes.

Service: Carrying steam, oil, air, gas and water at temperatures of −100 to +500 F and pressures to 250 psi; compensates for roll eccentricity and end play and piping misalignment.

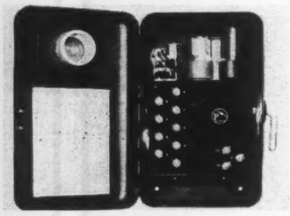
Design: Stationary-siphon type revolving joint; rotor turns on flat face of carbon disk; opposite face of disk is spherical and bears against a ball seat to allow for misalignment; inner seal is spring-loaded Teflon wedge, which allows for expansion; wearing metal surfaces are chromed for long life.

For more data circle MD 11, Page 209

PHOTOELECTRIC CONTROL 10

. . . has wide range of applications

Photoswitch Inc., 77 Broadway, Cambridge 42, Mass.



This control will withstand high temperature, humidity and vibration often encountered in industrial applications.

Designation: Series 20 and 21.

Size: $7\frac{7}{16}$ in. wide, $4\frac{15}{16}$ in. deep, 9⅝ in. high; weighs 11 lb.

Service: Opening or closing electrical circuit; contacts rated at 20 amp 115 v ac or 10 amp 230 v ac; require 115 or 230 v, 50-60 cycle ac power; light source may be 20 ft from photo tube; adjustable for operation between 10 and 50 ft-c; operates in 1/20 second after interruption of light beam.

Design: Photoelectric double-pole double-throw relay; ¼-in. diam silver contacts; uses vacuum tube amplifier; available with external or internal photo tube and with adjustable 1/5 to 5 second time delay; hermetically sealed oil-filled capacitors and high wattage resistors used.

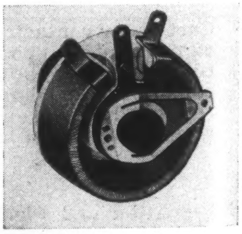
Applications: Counting; conveyor control; motor or valve control; machine safeguards.

For more data circle MD 10, Page 209

RING TYPE RHEOSTATS 12

. . . provide smooth control, without backlash

Ward Leonard Electric Co., Mount Vernon, N. Y.



Direct connection between control knob and contact shoes eliminates backlash.

Designation: 25R and 50R.

Size: 25R, $1\frac{9}{16}$ in. diam, $2\frac{3}{16}$ in. long including knob; 50R, $2\frac{5}{16}$ in. diam, $2\frac{11}{32}$ long including knob.

Service: Continuously varying electrical resistance; 25R rated 25 watts, resistances from 1 to 2500 ohm; 50 R rated 50 watts, resistances 1 to 7500 ohm; wattage ratings based on 300 C rise in ambient not over 40 C.

Design: Wire-wound rheostat or potentiometer; high stability special resistance wire; graphite contact shoes; base and core of molded high dielectric strength ceramic; mounts in $\frac{25}{64}$-in. diam hole on panels up to ¼-in. thick; requires 0.206-in. diam locating hole for retainer which prevents rotation; control knob of black Bakelite attaches with set screw; 25R rotation, 280 deg; 50R rotation, 300 deg; tapered windings available as specials.

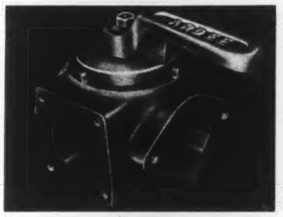
For more data circle MD 12, Page 209

NEW PARTS AND MATERIALS

RECIRCULATING VALVE 13

. . . available in a variety of materials

Ardee Mfg. Co. Inc., 840 N. Seward St., Los Angeles 38, Calif.



This valve will handle gases, air, oil, salt water and mild chemicals at pressures to 125 psi.

Size: 2 in. pipe.

Service: Stream dividing of gases, air, oil, salt water and mild chemicals to 125 psi; tests indicate minimum pressure drop and full pipe orifice flow.

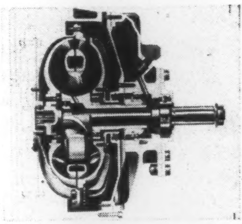
Design: Plug type recirculating valve; has O ring sealing; available in cast aluminum, cadmium-plated steel or cadmium-plated Navy bronze; flange connections for either male or female threads available; externally adjustable seating control permits adjustment for low handle loads and minimum internal wear without leakage.

For more data circle MD 13, Page 209

TORQUE CONVERTER COUPLING 14

. . . multiplies torque or acts as fluid coupling

Fuller Mfg. Co., Kalamazoo, Mich.



No external oil pump and oil cooler are needed for normal operation of this torque converter.

Designation: Model 12-A and 12-S.

Size: Mount on SAE No. 3 flywheel housing.

Service: Coupling engines developing 100 to 225 lb-ft torque with maximum speeds of 2000 to 2200 rpm to load; provides maximum torque multiplication of 2 to 1 with converter output shaft stalled; changes to 1 to 1 or fluid coupling operation as output torque requirements diminish; change from converter to coupling is fully automatic; operates on SAE 10 oil.

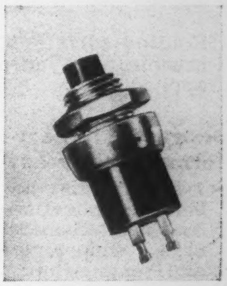
Design: Single-stage, two-phase hydraulic torque converter; stator mounted with overrunning clutch to allow operation as converter or coupling; 12-A has flanged output shaft and SAE No. 3 flywheel housing at rear permitting installation of flywheel, clutch and transmission; 12-S has 1½-in. ten-spline shaft for universal joint drives; sprockets, pulleys or gears must be independently supported on outboard bearings.

For more data circle MD 14, Page 209

PUSHBUTTON SWITCH 15

. . . only ½-in. in diameter

Grayhill Co., 4524 W. Madison St., Chicago 24, Ill.



This switch is approximately one-half the size of conventional "miniature" pushbutton switches made by this company.

Designation: No. 23-1.

Size: 1.047 in. long; ½-in. max diam; mounts in 11/32-in. diam drilled hole.

Service: Rated at ¼ amp, 115 v ac, noninductive; contact resistance, 0.007-ohm before use and 0.015-ohm after 200,000 operations; extremely long life is claimed.

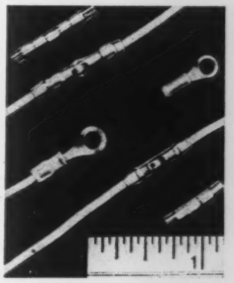
Design: Normally open, single-pole, single-throw pushbutton switch; momentary contact arrangement.

For more data circle MD 15, Page 209

TERMINALS AND CONNECTORS 16

. . . permit visual inspection of connections

Aircraft-Marine Products Inc., 2100 Paxton St., Harrisburg, Pa.



Transparent polyvinyl plastic insulating sleeves and small openings in connectors allow inspection of connections at a glance.

Designation: Ampli-Mite.

Size: Ring-tongue terminals ½ to $\frac{23}{32}$-in. long for stud sizes 0 to 10, slotted-tongue terminals $\frac{19}{32}$-in. long for stud sizes 0, 3 and 4; rectangular-tongue terminals $\frac{13}{16}$-in. long for stud sizes 5 and 6; butt connectors with insulation support sleeves, $\frac{57}{64}$-in. long, without insulation support sleeves, ⅝ in. long.

Service: Connecting or terminating No. 26 to No. 22 solid or stranded wires; resist twisting or vibration and are free from radio frequency noise.

Design: Crimp-on type terminals and connectors; body and insulation support sleeve of electrolytic copper; insulating sleeve of polyvinyl plastic extends beyond body to enclose wire insulation eliminating taping or separate insulating sleeves; insulating sleeve bonded to terminal or connector.

For more data circle MD 16, Page 209

VINYL COATING PRIMER 17

. . . is easy to apply

Prufcoat Laboratories Inc., 50 *E. 42nd St., New York* 17, *N. Y.*

Routine surface preparation methods such as wire-brushing are adequate when this primer is to be applied.

Designation: Heavy-Duty P-50.

Form: Liquid, ready mixed.

Service: Priming metal surfaces, ferrous or nonferrous, before application of topcoat; topcoats may be vinyl coatings, oleoresinous or oil paints; adheres well to brass, copper, lead, monel, iron, steel, aluminum, and magnesium; controls underfilm corrosion; can be brushed or sprayed; air dries overnight.

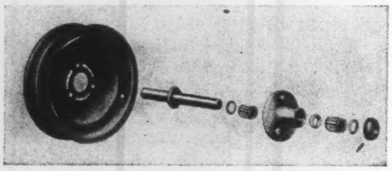
Properties: Heavy-bodied, oil modified synthetic resin vehicle with a high percentage of inhibitive pigments.

For more data circle MD 17, Page 209

WHEEL-SPINDLE ASSEMBLY 18

. . . for low load applications

French & Hecht Div., Kelsey-Hayes Wheel Co., 54 *E. River St., Davenport, Iowa.*



This wheel is intended for use in place of heavier, more expensive wheels.

Size: 15 x 4J drop-center rim; takes 15 in. tires up to 8.20 x 15.

Service: Carrying loads up to 750 lb per wheel.

Design: Assembly consisting of drop-center rim, cast hub, bearings, seals and 1¼ in. diam cold-rolled steel spindle.

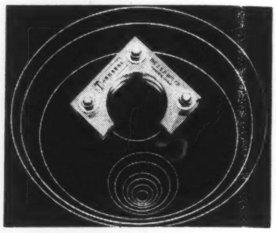
Application: Light trailers and similar wheeled equipment.

For more data circle MD 18, Page 209

O-RINGS 19

. . . made from metallic tubing

D. S. D. Mfg. Co., 2964 *Whitney Ave., Hamden, Conn.*



These O-rings will seal at temperatures up to 1000 F.

Designation: Toruseal.

Size: ½ to 48 in. diam; 0.031 to 0.250-in. OD.

Service: For stationary or limited sliding and rotary seals; seal from −150 to +1000 F at pressures to 1000 psi or more; unaffected by many strong and weak acids and alkalies at moderate temperatures.

Design: O-rings made from 18-8, AISI 316, 321, 347, 410, and 430 stainless steels, mild steel, Monel and Inconel seamless tubing; specials available to order.

For more data circle MD 19, Page 209

METALLIC LUBRICANT 20

. . . contains molybdenum disulfide

Imperial Oil & Grease Co., 6399 *Wilshire Blvd., Los Angeles* 48, *Calif.*

Molybdenum disulfide, graphite and a lead-copper alloy give this lubricant a very high film strength.

Designation: HT.

Form: NLGI 1, 2 and 3 consistency grease.

Service: Lubrication under both normal and extreme conditions; graphite and metallic additives impart extremely high film strength; heat and water resistant; pumpable in pressure systems or hand guns.

Properties: Grease made from mineral-oil and silicone base with molybdenum disulfide, graphite and lead-copper alloy added; ASTM dropping points from 310 to 510 F dependent upon consistency; work-normalized to prevent changes in consistency due to working while in use; will not melt; has high adhesion to metal surfaces.

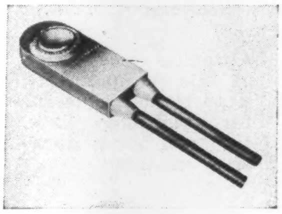
For more data circle MD 20, Page 209

NEW PARTS AND MATERIALS

WATERPROOF SWITCH 21

. . . operates from —65 to 165 F

Control Products Inc., 306 *Sussex St., Harrison, N. J.*



Completely enclosed in a silicone plastic cover, this switch is waterproof and explosion proof.

Size: $1\frac{13}{16}$ in. long, $\frac{13}{16}$-in. wide, $\frac{25}{64}$-in. thick.

Service: Rated at 10 amp 28 v dc; waterproof, explosion-proof; sealed against dirt and dust; will withstand vibration up to 106.5*g*; has passed 25,000 cycle life test with 21 amp resistive load at 26 v dc; made in accordance with U. S. Army Spec. 60-977-2 Class B, covering waterproof and corrosion resistance.

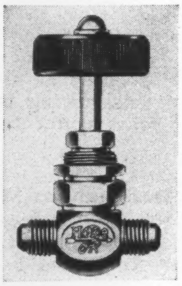
Design: Miniature snap-action switch using beryllium copper spring in shape of sine curve; switch mechanism enclosed in steel case and silicone plastic cover with molded-in 0.155-in. OD wire leads; basic design is off-momentarily on, also available with toggle and lever actuators and as single-pole double-throw toggle switch.

For more data circle MD 21, Page 209

PANEL MOUNTING VALVES 22

. . . available in brass, aluminum or stainless

Hoke Inc., 191 *S. Dean St., Englewood, N. J.*



Neat appearance and single hole mounting make these valves ideal for instrument panel mounting.

Size: 3¼ in. closed height, 0.620-in. wide, 1¾ in. long; approx. 0.060 or 0.170-in. orifice; 1 11/32 in. diam handle; mounting hole 41/64-in. diam; ⅛ and ¼-in. pipe sizes.

Service: Controlling flow of gases or liquids at pressures to 2000 psi; flow rate of valves with 0.060-in. orifice is 150 cu ft of air or 120 liters of water per hr at 50 psi pressure, with 0.170-in. orifice, 750 cu ft of air or 600 liters of water per hr at 50 psi pressure; packings withstand temperatures to 750 F.

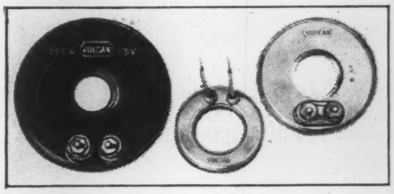
Design: Straight-line needle valves machined from brass, aluminum or stainless steel forgings; connect to standard pipe or tubing; black plastic handwheels; exposed parts of brass valves are nickel plated; packing of graphite-asbestos composition or Teflon; angle type valves also available.

For more data circle MD 22, Page 209

RING HEATERS 23

. . . new designs have wide application

Vulcan Electric Co., Danvers, Mass.



These heaters are easy to install and give highly concentrated heat.

Size: 6 sizes from 2 in. OD, ¼-in. thick to 6 in. OD, 5/16-in. thick.

Service: Ratings from 75 to 800 w in steel sheaths, from 200 to 1000 W in stainless steel sheaths; temperatures to 750 F for steel, to 1000 F for stainless steel; operate on 115 or 230 v.

Design: Electrical resistance heating element in ring-shaped steel or stainless steel case; threaded stud terminals standard; also available with flexible lead wires; available as three-heat models except smallest size.

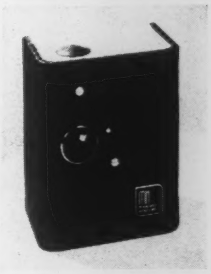
Applications: Space and contact heaters in vulcanizers, molds, dies and distillation equipment; for maintaining correct temperature of instruments.

For more data circle MD 23, Page 209

CUT-OFF RELAY 24

. . . provides process end-point control

Minneapolis-Honeywell Regulator Co., Industrial Div.,
Wayne and Windrim Aves., Philadelphia 44, *Pa.*



Used with an electric temperature or pressure controller and a solenoid or motor-operated valve, this relay stops the process when the end point is reached.

Size: 5¼ by 4 3/16 by 2⅝ in.

Service: Providing positive end-point control of automatically controlled processes; rated 13 amp at 115 v ac or 6.5 amp at 230 v ac; when used in circuit with thermostat and solenoid or motorized valves to control heating process, relay prevents reapplication of heat after end point has been reached despite subsequent cooling below desired temperature.

Design: Relay requiring manual closing; has green signal light which is on when contacts are closed.

Applications: Processes requiring automatic shutdown and manual resetting.

For more data circle MD 24, Page 209

NEW PARTS

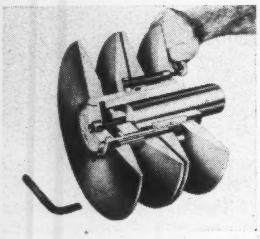
VARIABLE SPEED SHEAVES

25

. . . have single-point adjustment

Dodge Mfg. Corp., Mishawaka, Ind.

One screw adjusts the pitch diameter of this sheave quickly and positively.



Designation: VR Taper-Lock.

Size: 2 or 3 belt; pitch diam variable from 5.5 to 10.0-in.; companion sheaves 10.0 to 20.0 in. pitch diam; for 1¼, 1⅝ and 1⅞ in. diam. shafts; companion sheaves for $\frac{15}{16}$ to 3 in. diam shafts.

Service: Varying speed over a range of approximately 1.82 to 1; maximum allowable speed, 5000 lineal fpm; maximum horsepower transmitted, approximately 30.

Design: Variable pitch sheaves; adjustment made by turning one socket head screw; sheave is locked on shaft by the turn of a screw; belts and motor bases available.

For more data circle MD 25, Page 209

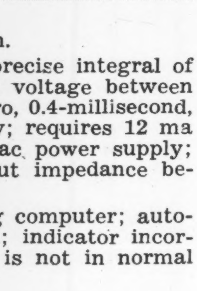
INTEGRATING COMPONENT

26

. . . for analog computers

George A. Philbrick Researches Inc., 230 *Congress St., Boston* 10, *Mass.*

This unit is designed to be used as a "building block" in the assembly of analog computers.



Designation: K3-J.

Size: 4½ in. wide, 5 in. deep, 7 in. high.

Service: Continuously computing a precise integral of the input voltage; range of input voltage between ±50 v; time factor selection of zero, 0.4-millisecond, 4 milliseconds, 1 second or infinity; requires 12 ma at 300 v dc and 50 ma at 115 v ac power supply; input impedance 1 megohm, output impedance below 1 ohm.

Design: Integrating electronic analog computer; automatic zero for initial stabilization; indicator incorporated to show if input voltage is not in normal range.

For more data circle MD 26, Page 209

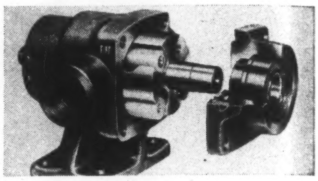
ROLLER-VANE PUMP

27

. . . for abrasive solutions

Hypro Engineering Co., 404 *N. Washington Ave., Minneapolis* 1, *Minn.*

Abrasion resistance of this pump makes it particularly useful for pumping lime, talc and other abrasive solutions.



Designation: 4000 Series.

Size: ¾-in. inlet and outlet ports; weighs 4½ lb.

Service: Pumping abrasive solutions; delivers approximately 7½ gpm at 100 psi at 1750 rpm; maximum recommended speed, 1800 rpm; maximum recommended pressure, 200 psi; self-priming, self-lubricated.

Design: Roller-vane type hydraulic pump; rollers of nylon or Hycar rubber; body and rotor of cast iron or Ni-Resist; sealed lubricated ball bearings are press fit on stainless steel shaft.

For more data circle MD 27, Page 209

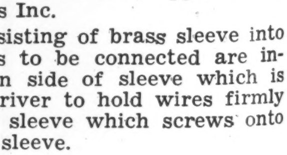
WIRE CONNECTOR

28

. . . makes well insulated connections

Holub Industries Inc., Sycamore, Ill.

Wire splices may be inspected at any time by unscrewing the shell of this connector.



Designation: MA-1, -2.

Size and Service: Making wire connections or splices; MA-1 will connect two No. 12 solid or stranded wires and various combinations of smaller sizes; MA-2 connects two No. 10 solid or stranded wires and combinations of smaller sizes, for example, three No. 12 solid and two No. 16 stranded; available in cartons of 100; approved by Underwriters' Laboratories Inc.

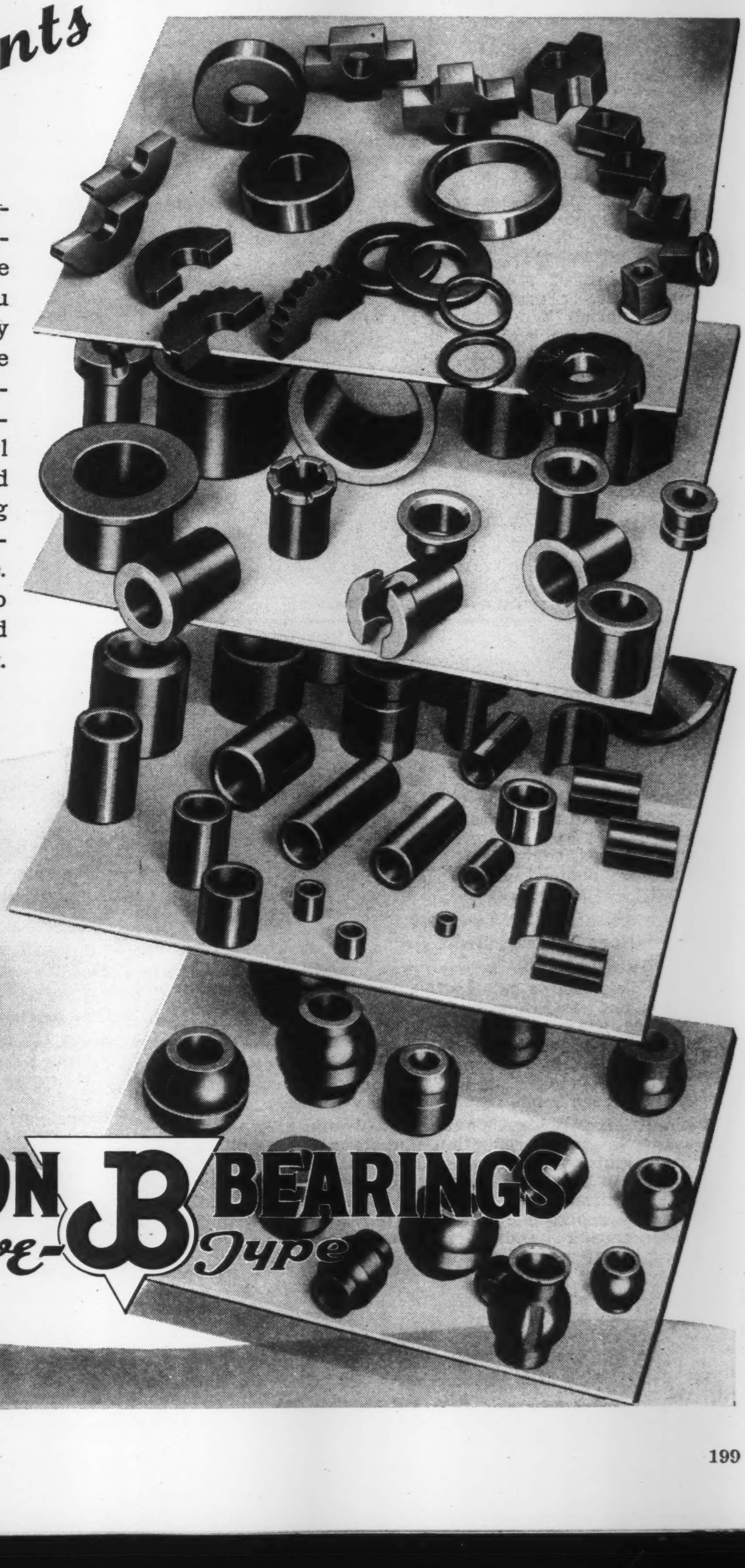
Design: Wire connector consisting of brass sleeve into which bare ends of wires to be connected are inserted, brass set screw in side of sleeve which is tightened with a screw driver to hold wires firmly and a Bakelite insulating sleeve which screws onto threaded portion of brass sleeve.

For more data circle MD 28, Page 209

POWDER METALLURGY

BEARINGS
BUSHINGS
AND PARTS

Send us your blueprints



THERE are many applications where powder metallurgy bearings and parts give utmost service. In these cases you can save considerable money. They are molded to shape and require no machining. They are impregnated with oil and in service become self-lubricating. Ledaloyl powder metallurgy bearings and parts are ideal for self-aligning bearings and for applications difficult or impossible to lubricate. Johnson engineers will gladly help you decide whether you should use them. Write for appointment.

JOHNSON BRONZE CO.,
525 S. Mill St., New Castle, Pa.

Ledaloyl
SELF LUBRICATING

SELF-
LUBRICATING

Many Sizes of plain, flanged and self-aligning bearings may be ordered from stock.

JOHNSON JB BEARINGS
Sleeve-Type

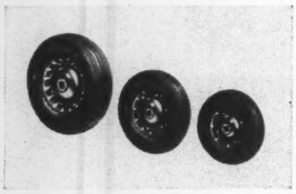
NEW PARTS AND MATERIALS

PRESSED STEEL WHEELS 29

. . . carry loads to 300 lb

Indus Corp., 431 *N. Holmes, Indianapolis* 22, *Ind.*

These wheels are available with semipneumatic, pneumatic, or solid tires.



Size: 6 to 14 in. tire size; bearing bores ½-in. diam for ball bearing, ½ and ⅝-in. diam for oil retention type; hub width, 1⅝ to 3¼ in.

Service: Carrying loads up to 300 lb dependent upon size and type of tire; ratings based on recommended max speed of 5 mph; can be operated at higher speeds with reduced loads.

Design: Pressed steel wheel mounting solid, semipneumatic or pneumatic tire; have either ball or oil retention type bearings; rim design prevents creepage of wheel on rim; standard finish, red sprayed baked enamel; also available finished to customer specification; available with ball bearings bored to ⅜, $\frac{7}{16}$ or ⅝-in. diam.

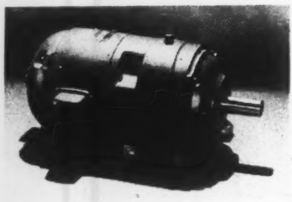
For more data circle MD 29, Page 209

GEAR MOTOR 30

. . . designed to simplify maintenance

General Electric Co., Small and Medium Motor Dept., Schenectady 5, *N. Y.*

Stator may be quickly removed and replaced in the event of failure without disturbing gearing or connection to load.



Designation: Tri-Clad Gear.

Size: 1 to 75 hp.

Service: Speeds of 13.5 to 780 rpm; Class I for steady loads not exceeding motor rating and 8 hr per day service; Class II for steady loads not exceeding motor rating and 24 hr per day service or for moderate shock loads in 8 hr per day service; Class III for moderate shock loads in 24 hr per day service or for heavy shock loads in 8 hr per day service.

Design: Ac polyphase or dc shunt-wound gear motors; single or double-reduction planetary gears; all open style motors are dripproof; mounting feet on gear reduction unit make removal of stator possible without disturbing gearing or connection to load; stator may be replaced by standard-motor stator with feet by mounting standard stator upside down to prevent foot interference; available as specials to 200 hp.

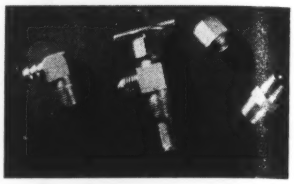
For more data circle MD 30, Page 209

VALVES AND FITTINGS 31

. . . cadmium plated to prevent rust

Dexter Automatic Products Co., Dexter, Mich.

Valves may be equipped with wire cloth strainers to eliminate sediment bowls in certain applications.



Size: Barbed fittings, $\frac{3}{16}$ to $\frac{5}{16}$-in. ID flexible tubing; $\frac{3}{16}$-in. tube male and female flared and compression fittings; ⅛-in. pipe-thread fittings.

Service: Connecting tubing and hose, and controlling flow; for gasoline, wood alcohol, light oil or corrosive fluids; resist corrosion.

Design: Valves and fittings machined from steel and cadmium plated; valves available in straight-through or angle type; strainers of 60 or 120 mesh Monel or bronze-wire cloth available in valves.

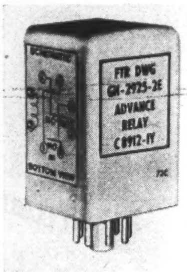
For more data circle MD 31, Page 209

HERMETICALLY SEALED RELAY 32

. . . operates on low amount of power

Advance Electric and Relay Co., 2435 *N. Naomi St., Burbank, Calif.*

Built to operate from −65 to 85 C and to 80,000 ft altitudes.



Designation: Series 4000.

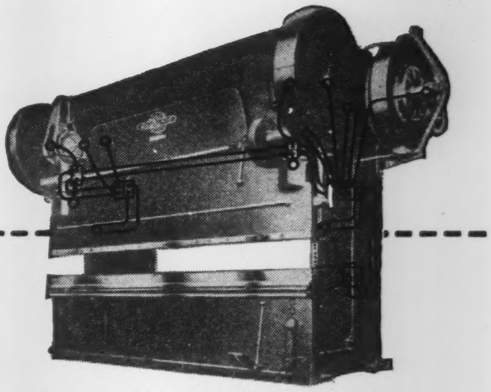
Size: 1½ x 1½ in.; 2½ in. high, not including plug.

Service: Opening or closing electrical circuits; sensitivity is 9 milliwatts for single-pole single-throw models, 15 milliwatts for double-pole double-throw models; coil resistance to 50,000 ohm; silver contacts rated 1.5 amp at 24 v dc resistive, palladium contacts rated 3.0 amp at 24 v dc resistive; withstands severe humidity, salt spray and dust; withstands 10g vibration.

Design: Hermetically sealed single-pole single-throw or double-pole double-throw relay; available with silver or palladium contacts; available with solder lug terminals or octal plug.

For more data circle MD 32, Page 209

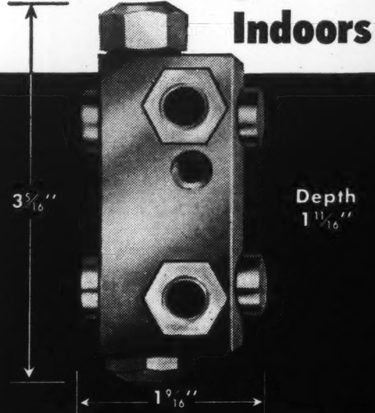
Designed! **to increase machine hours**
...reduce man hours



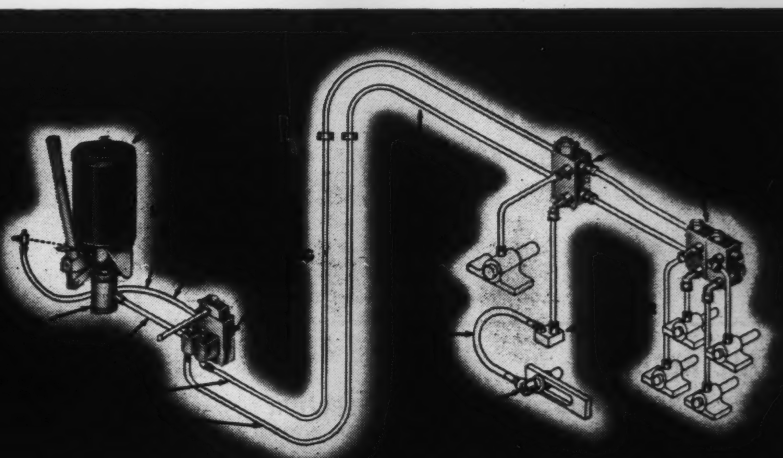
Alemite Type II Accumeter lubricates all 13 points simultaneously on Press Brakes manufactured by Doelger & Kirsten, Inc., Milwaukee, Wisconsin.

ALEMITE
Accumeter
AUTOMATIC LUBRICATION

Fights Friction Everywhere...Outdoors in Any Weather Indoors in Grit-Laden Air or Heavy Industrial Fumes



Type II Accumeter Valve
Each serves two bearings. In four sizes, delivering from .010 to .500 cu. in. of lubricant. Adjustable, fully hydraulic, no springs. System serves up to 600 bearings. Manual or automatic operation.



brings all these advantages!

- Eliminates shutdown time for lubrication. *Adds* productive time to machine output.
- Seals completely against dirt, grit, water all the way from "Barrel-to-Bearing."
- Prevents bearing troubles due to neglect or use of wrong lubricant.
- Services *all* bearings—including those inaccessible or dangerous—in one operation.
- Avoids work spoilage and bearing repairs due to over-lubrication.

Factory-Tested... Field-Proved!
Exhaustive tests showed *no variation* in the amount of lubricant discharged . . . even after 73,312 lubrication cycles, *equal to 122 years of twice-a-day service.* Proved in the field, where one big-plant installation reduced lubrication costs $3,527 in only 65 days!

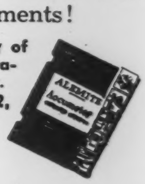
For Tough-Job Lubrication of Heaviest Machines!

From one central point, Alemite Accumeter Lubrication System delivers the exact, measured amount of oil or grease to *all* bearings of a machine. In seconds—in a fraction of the time required for hand lubrication—Accumeter *automatically* measures and delivers lubricant . . . *while the machine is in operation.* No downtime for lubrication . . . no points missed!

Type II Accumeter cuts costs, boosts production under conditions that would render other systems inoperative. It is unaffected by gritty, highly abrasive atmosphere—*because it is fully sealed and enclosed!* Operates in salt spray, severe acid or fume conditions, even totally immersed—*because it may be painted or treated with non-corrosives.* For all extremes of weather or temperature—from sub-zero to 200°F.

Adds years of productive time to the heaviest machines. Type II Accumeter can serve groups of machines and will handle every oil or grease that can be pumped. It is just one of three types of Accumeter systems. One of them will serve *your* requirements!

SEND NOW for your free copy of this new Alemite Accumeter Catalog and Engineering Data Book. Address: Alemite, Dept. R-122, 1850 Diversey Parkway, Chicago 14, Ill.



A PRODUCT OF SW STEWART WARNER

ALEMITE
REG. U.S. PAT. OFF.

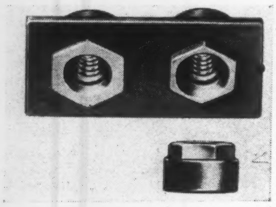
NEW PARTS

INSERT NUT

33

. . . can be applied after painting

Grip Nut Co., 320-8 S. Michigan Ave., Chicago 4, Ill.



Used in a hexagonal hole, this nut cannot turn after installation.

Designation: Gripco "Clinch"

Sizes: 8-32, 10-32, ¼-in., 5/16-in., ⅜-in., 7/16-in., and ½-in.; standard or fine threads.

Service: In blind assemblies or for additional thread depth in thin metals; may be used in aluminum, brass and other metals which cannot be projection welded.

Design: Insert nuts made of steel, stainless steel, brass or aluminum; hexagon pilot is pressed down and flattened after insertion to clinch the nut securely in place; also available with locking threads.

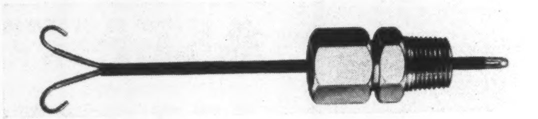
For more data circle MD 33, Page 209

MIDGET PACKING GLAND

35

. . . of stainless steel

Conax Corp., 4515 Main St., Buffalo, N. Y.



A means of inserting thermometers, thermocouple wells or electric wires into closed vessels under pressure.

Size: 1⅛ in. long, ½-in. hex; for 3/32, ⅛, 3/16-in. diam tubes; ⅛-in. pipe threads for installation.

Service: Providing a sealed means of entry into pressure or vacuum systems for thermometers, thermocouple wells, pitot tubes, pressure probes, round rods, tubing or electric wires; resists corrosion.

Design: Packing gland; packing of Neoprene or asbestos graphite is compressed by gland follower, eliminating rotary slippage during assembly; made from type 303 stainless-steel cold-drawn bar stock; available for intermediate diameters of tubing on special order.

For more data circle MD 35, Page 209

BALL BEARINGS

34

. . . high capacity with thin section

Split Ballbearing Corp., Lebanon, N. H.

Prelubricated, these bearings may be used in hard to get at locations.

Designation: DR-L.

Size and Service:

Bearing No.	Bore (in.)	OD (in.)	Width (in.)	Max Speed* (rpm)	Max Cap* (lb)
DR-07-L	0.4375	1.000	0.625	1850	795
DR-08-L	0.5000	1.000	0.625	1800	795
DR-10-L	0.625	1.125	0.625	1500	920
DR-12-L	0.750	1.250	0.625	1280	1025
DR-14-L	0.875	1.375	0.625	1110	1215
DR-16-L	1.000	1.500	0.625	1000	1370
DR-18-L	1.125	1.625	0.625	900	1500
DR-20-L	1.250	1.750	0.625	800	1625
DR-22-L	1.375	1.875	0.625	750	1760
DR-24-L	1.500	2.000	0.625	690	1900
DR-26-L	1.625	2.125	0.625	640	2035
DR-28-L	1.750	2.375	0.750	630	2840
DR-30-L	1.875	2.500	0.750	595	3000
DR-32-L	2.000	2.625	0.750	555	3200
DR-34-L	2.125	2.750	0.750	525	3390
DR-36-L	2.250	2.875	0.750	495	3500
DR-38-L	2.375	3.000	0.750	475	3680
DR-40-L	2.500	3.125	0.750	450	3860

* Max speed and max capacity may not be used concurrently.

Design: Double-row thin-section ball bearings; full complement of balls; prelubricated; available with +0.0000, −0.0055-in. bores for press fit on shaft or +0.001, −0.0015-in. bores for free fit on shaft; will take thrust loads when outer race is press fitted.

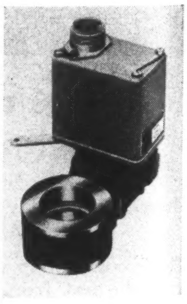
For more data circle MD 34, Page 209

MOTORIZED GATE VALVE

36

. . . is light and compact

Hydro-Aire Inc., 3000 Winona Ave., Burbank, Calif.



Using Teflon seals, this valve may be used with gasoline and oil as well as air, water or gases.

Size: 5 in. high, 4⅜ in. long; valve proper is 1 5/16 in. thick; ¾, 1, 1¼, 1½, 2, 2½, 3 or 4 in. fluid connections.

Service: Controlling flow of water, oil, gasoline, alcohol, air or other gases; operating time, 1 second max; temperature range, −65 to 165 F; working pressure, 65 psi; proof pressure, 200 psi; flow may be in either direction; operates on 18 to 30 v dc.

Design: Motorized gate valve; all seals of Teflon; limit switch requires no adjustment and positively prevents valve action stopping in mid-position; manual override incorporated which completely bypasses motor and gear train and requires no more operating torque than manually operated valve of same size; electrical connections in accordance with AN 3102C-14S-SP and AND 1006-14S-SP; mounting per AND 10086; also available in manually operated version.

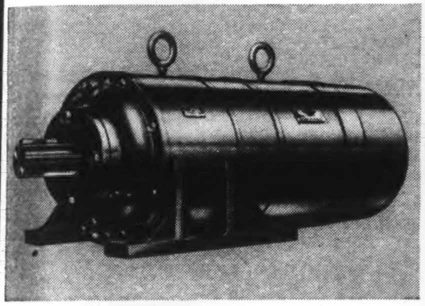
For more data circle MD 36, Page 209

Advertisement

Unit Assemblies of Motor, Speed Reducer and Brake Simplify Designs

Designers of motor-driven equipment which must provide for both speed reduction and a means of stopping the machine rapidly, find that it is frequently possible to simplify their product designs through the use of integral, compact assemblies of motor, speed reducer and brake.

Space-saving is an important benefit, since the integral assembly is considerably more compact than three separate units. Moreover, it is unnecessary for the designer to provide for means of coupling or assembling the units.



Typical Gear-Brakemotor design, showing the compactness of the assembly

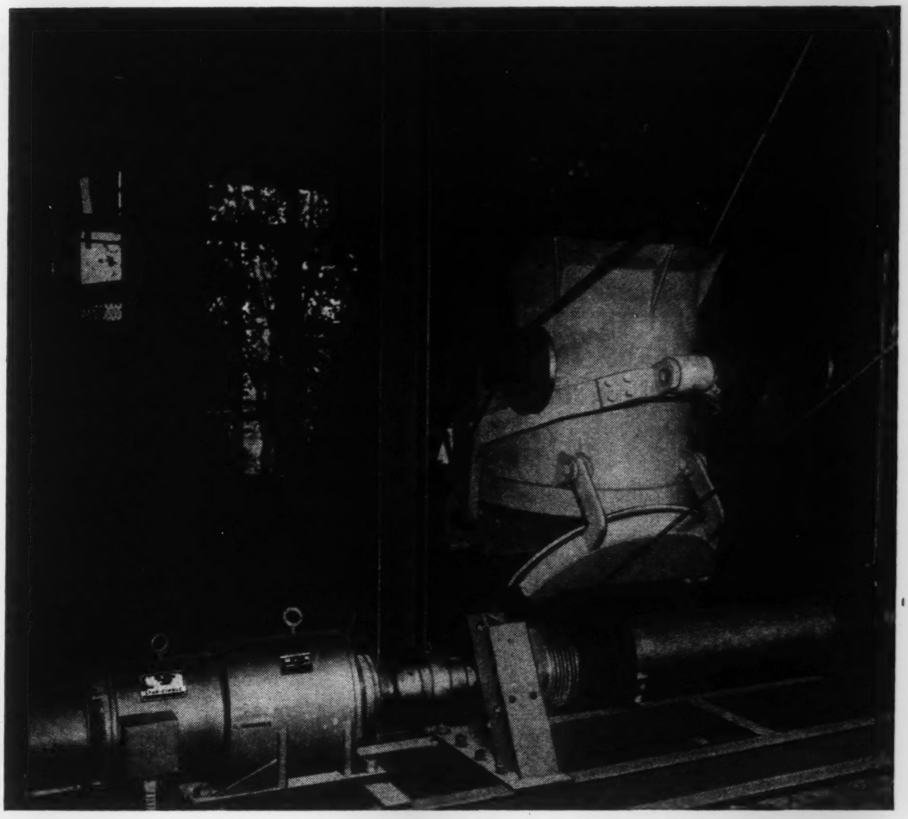
Adaptability to Varying Requirements

While the complete Gear-Brakemotor is a unit assembly, a very wide latitude is possible in selecting the individual components. Star-Kimble, the manufacturer of this type of motor, is prepared to supply a considerable range of motor ratings, braking torques and speed ratios.

It is the practice of many product designers merely to furnish Star-Kimble with the details of service requirements. Star-Kimble engineers then design the complete unit to meet these requirements, with all parts built to work together smoothly and efficiently. From the standpoint of the product designer, this procedure has the advantages of simplifying his own calculations, and also of establishing unified responsibility for the functioning of the complete unit.

The braking unit used in these Gear-Brakemotors is the same design employed in Star-Kimble Brakemotors supplied without the speed reducer feature. These Brakemotors have consistently proved their merits in every type of service calling for fast stops and starts on a heavy duty cycle.

Further information is contained in Bulletin B-501-A, available from Star-Kimble Motor Division of Miehle Printing Press and Mfg. Co., 201 Bloomfield Avenue, Bloomfield, New Jersey.



"YEARS OF LIFE IN TOUGHEST FOUNDRY SERVICE"

. . . say Whiting Engineers of Star-Kimble Gear-Brakemotors

The Whiting Skip Charger shown in the photo works two shifts a day, handling heavy charges of metal, coke and stone for the cupola. The Skip Charger must stop the load *accurately* and hold it *positively*. Equipment is subjected to intense heat and heavy concentrations of dirt in the air.

For tough service like that, Whiting powers its equipment with Star-Kimble Gear-Brakemotors, which have *proved* their ability to give years of service with little need for maintenance attention. The quick-acting, positive brake requires little or no adjustment; the motor and speed reducer provide a high factor of safety for heavy overloads. AND . . . motor, brake and speed reducer are a *single*, compact, well-protected unit.

For information on Star-Kimble Brakemotors, with or without the speed-reducing feature, write for Bulletin B-501-A.

STAR-KIMBLE
MOTOR DIVISION
MIEHLE PRINTING PRESS AND MFG. CO.
201 Bloomfield Avenue Bloomfield, New Jersey

ENGINEERING DEPARTMENT

EQUIPMENT

For additional information on this new equipment, see Page 209

DRAFTING BOARDS 37

. . . have self-paralleling straightedges

Bradford Bailey Co., P.O. Box 440-82, Elizabeth, N. J.

An indicator shows the amount of movement of the straightedge, simplifying the drawing of equally-spaced parallel lines.

Designation: PAR-L-L-ER.

Size: 12 x 13 in., 15 x 19 in. or 21 x 25 in.

Service: For drawing parallel lines and general drawing; easily portable and extremely sturdy.

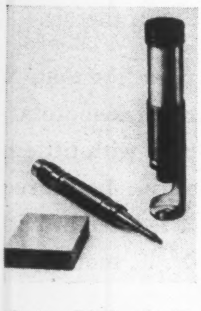
Design: Lightweight pressed wood board with hard-finished treated surface; marble-gray color; cord and pulley arrangement maintains straight-edge in parallel position.

For more data circle MD 37, Page 209

HARDNESS TESTER 38

. . . small enough to be carried in pocket

Pacific Transducer Corp., 11921 *W. Pico Blvd., Los Angeles* 64, *Calif.*



Though small, accuracy of this tester is ±1½ points, Rockwell C scale.

Designation: Model 316.

Size: Carrying case, approximately 2 in. high, 3 in. wide and 6 in. long.

Service: Measuring surface hardness of steel alloys and other metals over range of 25 to 65 Rockwell C.

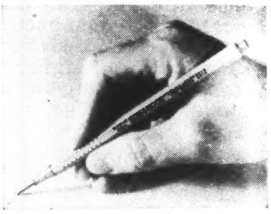
Design: Impact indentor which drives $\frac{1}{16}$-in. diam tungsten-carbide ball into sample to be tested; microscope with calibrated reticle to read Rockwell hardness directly from indentation; standard-hardness test block included for checking accuracy.

For more data circle MD 38, Page 209

LEAD HOLDER 39

. . . pushbutton operated for rapid feeding

Koh-I-Noor Pencil Co., Bloomsbury, N. J.



Knurled for easy, slip-proof manipulation.

Designation: 5612 Versatil.

Size: 5⅝ in. long.

Service: Holding standard-size drawing leads; lead is securely held and guaranteed not to slip; easily disassembled.

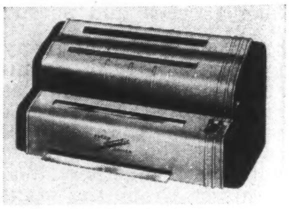
Design: Chuck type lead holder with pushbutton-operated lead-feeding mechanism; knurled body.

For more data circle MD 39, Page 209

PHOTOCOPYING MACHINE 40

. . . processes finished copies in 30 seconds

American Photocopy Equipment Co., 2849 *N. Clark St., Chicago, Ill.*



Compact unit exposes and develops prints in two steps.

Designation: Apeco Auto-Stat.

Size: 20¾ in. long, 10 in. wide, 11 in. high; copies to 11 x 17 in.

Service: Copies papers and documents printed on one or both sides of opaque or translucent paper; furnishes black and white positive copy, reverse-reading negative; inexperienced operator can produce 100 copies per hr; plug-in ac or dc operation; process uses no trays, requires no washing.

Design: Uses two specially coated papers; original is passed through the exposure section of the machine with one type of paper; exposed paper and second type of paper are then passed through printing section of machine to make positive copy.

For more data circle MD 40, Page 209

Send
DOW
MAGNESIUM
FINISHING

FOR DOW'S NEWEST BOOK ON

MAGNESIUM FINISHING

contains latest information on

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- Magnesium-to-Dissimilar Metals

- √ **Methods**
- √ **Materials**
- √ **Preparation**
- √ **Procedure**

The expanding use of magnesium, its extensive possibilities and the ever-increasing interest in this ultralight metal have resulted in a demand for more information regarding finishing procedures for magnesium products. Hence this book, which is a complete compilation of the latest information on magnesium finishes including: chemical treatments, painting methods and assembly protective measures.

If you are using magnesium now or contemplate using it in the future, you will find this book of vital importance. For your copy of "Magnesium Finishing" simply write to Dept. MG 97 using your company letterhead.

DOW
MAGNESIUM

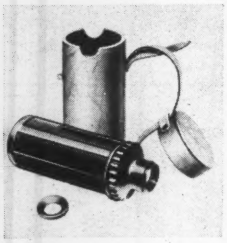
THE DOW CHEMICAL COMPANY
Magnesium Department • Midland, Michigan
New York • Boston • Philadelphia • Atlanta • Cleveland • Detroit • Chicago
St. Louis • Houston • San Francisco • Los Angeles • Seattle
Dow Chemical of Canada, Limited, Toronto, Canada

OPTICAL PYROMETER 41

. . . measures temperatures to 3300 F

Allied Engineering Div., Ferro Corp., 4150 *E.* 56*th St., Cleveland, O.*

Can be calibrated by sighting upon any bright object at room temperature.



Size: $6\frac{1}{2}$ in. long, $2\frac{1}{3}$ in. diam; weighs $5\frac{1}{3}$ oz.

Service: Measuring temperatures to 3300 F; calibration accomplished by aiming at any bright object at room temperature and turning eyepiece to bring indicator to zero.

Design: Convergent lens focused on bimetal spring with attached pointer; free end of bimetal spring is corrected by a second bimetal spring not influenced by radiation; operator looks through eye piece to aim the pyrometer and read temperature; red glass disk to protect the eye is furnished; case included.

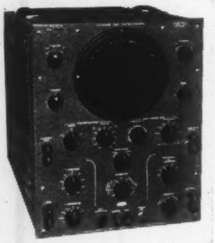
For more data circle MD 41, Page 209

OSCILLOGRAPH 42

. . . has high accelerating potential

Allen B. Du Mont Laboratories Inc., Instrument Div., 1500 *Main Ave., Clifton, N. J.*

Precise observation and measurement of extremely rapid phenomena are possible with this instrument.



Designation: 303-AH.

Size: 16 in. high, $12\frac{1}{8}$ in. wide, $19\frac{3}{4}$ in. deep; weighs 84 lb; 5 in. screen.

Service: Vertical amplifier band width, 10 megacycles; linear sweep speed, 10 in. per microsec; can be used to measure voltage, frequency, pulse amplitude and pulse duration; pulse response of 0.033-microsec; built-in sweep-time calibration; vertical deflection factor, 0.016-v per in.; maximum vertical input, 600 v dc plus peak ac; operates on 115-230 v ac 50 or 60 cycles per sec.

Design: Cathode-ray oscillograph; has illuminated calibrated scale for precise visual measurements or photographic recording; heavy calibration lines at 1 in. horizontal and ½-in. vertical intervals; shielded coaxial input adapter to match 52, 75 or 93 ohm coaxial line; direct connection to deflection plates through side panel can be made; housed in blue-gray wrinkle metal cabinet with two carrying handles; etched, white-filled numerals.

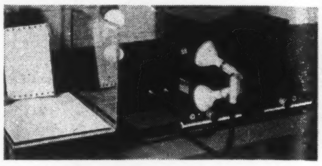
For more data circle MD 42, Page 209

PHOTOCOPYING CAMERA 43

. . . makes reproductions by xerography

Haloid Co., Haloid St., Rochester 3, *N. Y.*

All equipment necessary for making the enlargements or reductions will fit on a 2 x 5 ft. table.



Designation: No. 3 XeroX.

Size: Length, with copy board extended, 73 in.; width, including lights, 58 in.; height, excluding table (not furnished), 22 in.; copy-board and max original size, 17 x 22 in.

Service: Exposing XeroX (xerographic electrostatic process) plates from which offset paper masters for use on an offset duplicator can be made; copies can also be made in a drawing-reproduction machine using XeroX translucent print as original copy; copy can be reproduced from 50 to 150% of original size.

Design: Rack and gear focussing bellows camera with *f*10, $10\frac{1}{4}$ in. focal length process lens; counter-balanced, tilting copy board with clamping glass cover for holding copy in vertical position is mounted on camera rack frame; four 150 w photoflood bulbs also mounted on rack frame; lens board or camera back focussing on ground-glass back or by percentage scale; electrically operated shutter with 0 to 60 sec electrical timer.

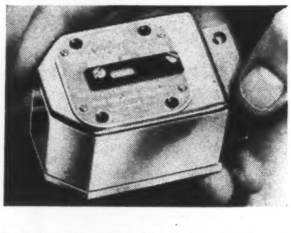
For more data circle MD 43, Page 209

VIBRATION PICKUP 44

. . . can be used at 500 F temperature

MB Mfg. Co., 1060 *State St., New Haven* 11, *Conn.*

Sensitive and rugged, this pickup can be used over a frequency range of 5 to 2000 cycles per sec.



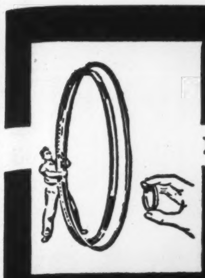
Designation: 122.

Size: $1\frac{7}{16}$ in. high, $1\frac{19}{32}$ wide, $2\frac{13}{32}$ in. long; weighs 9.7 oz.

Service: Converting vibration to electrical voltage proportional to velocity of vibrational component perpendicular to its base; frequency range 5 to 2000 cycles per sec; temperature range −50 to 500 F; no practical lower limit of amplitude; upper amplitude limit 0.6-in.; output is 21.0 mv rms per 0.001-in. double amplitude at 100 cycles per sec or 0.0945-v per in. per sec; coil resistance, 600 ohm.

Design: Small coil on end of pivoted shaft moves in magnetic field of Alnico magnets; neoprene stops limit arm movement; electrically damped; extreme lightness of moving parts allows severe use without damage; uses ring type jewel bearings; mounts with four No. 6 machine screws through body; furnished with locking connector and 18 in. unshielded pigtail lead; shielded pigtail can be supplied; special adaptations available.

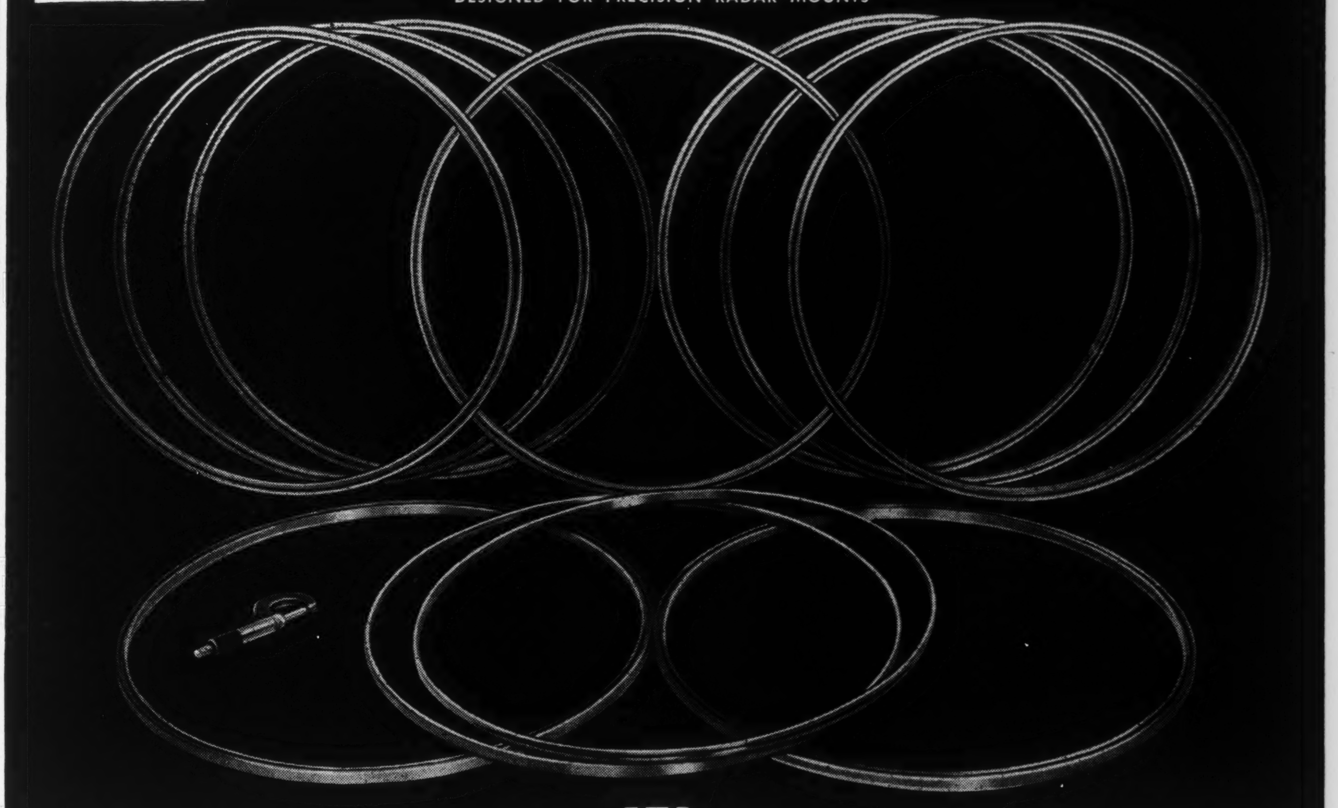
For more data circle MD 44, Page 209



Contact KAYDON Muskegon

FOR ALL TYPES OF BALL AND ROLLER BEARINGS: 4" BORE TO 120" OUTSIDE DIAMETER

KAYDON BALL RADIAL BEARING — 16.875" x 17.625" x 0.375"
DESIGNED FOR PRECISION RADAR MOUNTS



ACTUAL SECTION: ONLY 3/8" x 3/8" **NET WEIGHT: 2 Pounds**

WORLD'S THINNEST BEARINGS

THIN AS A WEDDING RING... WITH THE PRECISION OF FINE WATCH PARTS

Proportionately, that's an understatement! A wedding ring as big as 17.625" outside diameter would be about four times as thick as the actual 0.375" section of these thin **KAYDON** bearings... and even the finest watch parts, enlarged proportionately, probably would not have the precision tolerance to which these bearings are consistently finished. • These are by far the thinnest ball bearings ever made in this large diameter. **KAYDON** has developed the facilities and special techniques vital to such precision production.

Precision miracles in extremely large bearings of unusually thin section have become routine achievements at **KAYDON**. In addition to unique thinness that conserves space and weight, other outstanding features have been embodied in many special **KAYDON** bearings ... for instance: Flame hardened bearing races drilled, tapped and gear-cut by the **KAYDON** process eliminate costly auxiliary parts, help improve machine design and performance, and make possible more compact, lighter machines of greater capacity.

For unusually large, light weight, thin section bearings, contact **KAYDON** of Muskegon.

KAYDON Types of Standard and Special Bearings:
Spherical Roller • Taper Roller • Ball Radial • Ball Thrust
• Roller Radial • Roller Thrust • Bi-Angular Bearings

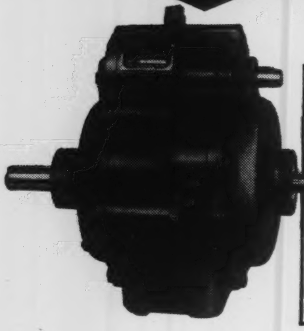
THE KAYDON ENGINEERING CORP.

MUSKEGON • MICHIGAN

PRECISION BALL AND ROLLER BEARINGS

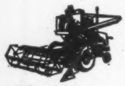
Here's Why
S·N's
Your Buy
for Quick,
Smooth
Reversing

AIR CARGO CONVEYOR, manufactured by Hicksville Fabricators Inc., Hicksville, N.Y. uses S-N Reversing Transmission.



SNOW-NABSTEDT
5107 Reversing Transmission

REVERSES
1. Without hesitation
2. Under full load
3. Smoothly, quietly
Transmits up to 10 H.P.
3.75:1 Reduction forward and reverse

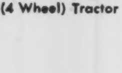


*Combine

*Road Roller

*Winch

*Power Mower



*(4 Wheel) Tractor

*Bulk Material Handling Truck

Anyone with an eye for economy will readily recognize the logic in buying one piece of equipment that does the work of four! It SAVES the purchase price of the other three (in many installations, the S-N Reversing Transmission eliminates a separate gear box, clutch, countershaft and mounting brackets). It SAVES space, too. You can pocket these SAVINGS or pass them on to your customers to give you a competitive advantage. No wonder so many are saying "S-N's the Buy for me!" For complete details, WRITE TO-DAY.

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HANDLING & FARM EQUIPMENT

DIRECTING POWER
FOR GREATER PROFIT
Since 1906

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SNOW-NABSTEDT
GEAR CORPORATION
★ 237 Welton Street, Hamden, Connecticut ★

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237 Welton St., Hamden, Conn.
Gentlemen: Kindly send Ind. Reduction Gear Catalog. Our equipment application is: ....
NAME .... TITLE ....
COMPANY ....
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CITY .... STATE ....

MEN OF MACHINES

The appointment of **A. O. Williams** as director of engineering has been announced by the Industrial Truck Div. of Clark Equipment Co., Battle Creek, Mich. In his new position Mr. Williams will coordinate the company's engineering activities in the field of materials handling equipment.

The Ferro Corp., Cleveland, has named **Glenn H. McIntyre** to the post of technical director and **Orville O. Kenworthy** as director of research. Dr. McIntyre, who will also continue in his present post as vice president of the corporation, will supervise the technical work of all branches, divisions and subdivisions of the company. He has been associated with Ferro since 1927; Mr. Kenworthy, who was appointed assistant director of research in 1951, joined the company in 1946.

◆

Formerly assistant general manager of the Engineering Works Div., **W. L. Newhall** has been appointed director of the department of research and development for Dravo Corp., Pittsburgh, and its subsidiaries. New assistant directors are **C. R. Horton Jr.** and **A. J. Liebman.**

◆

Succeeding **E. E. Forstrom,** who will retire in the early part of next year, **Owen L. Taylor** has been named manager of engineering for the Bryant Electric Co., Bridgeport, Conn., a wholly owned subsidiary of the Westinghouse Electric Corp., Pittsburgh. In 1939 Mr. Taylor joined the company's East Pittsburgh plant, later transferred to the Standard Control Div. at Beaver, Pa., as a senior engineer, and joined Bryant in June of last year.

◆

Having served as engineer for 19 years, **Carl E. Johnson** has been appointed chief engineer at Scaife Co., Oakmont, Pa. At the same time announcement was made of the appointment of **James S. Shuster** as product engineer of the pressure vessel division.

◆

W. C. Sealey has been named chief engineer, transformer section, of the power department of Allis-Chalmers Mfg. Co., Milwaukee. Other new appointments in this section include those of **K. P. Wiederkehr** to engineer in charge of transformer design, **R. P. Marohn** to engineer in charge of regulator design, and **D. T. Scag** to engineer in charge of betatron design. Allis-Chalmers has also made several other new appointments in its power department. **George A. Adlam** is now application engineer in the blower and condenser section, and **Bernard M. Koetting** and **Stanton H. Telander** are assistant engineers in the motor and generator section and switchgear section, respectively.

◆

Howard E. Earl recently joined the Sundstrand Machine Tool Co., Rockford, Ill., as chief engineer in charge of an engineering department for the development of pneumatic and magnetic products. He will be responsible for co-ordinating the design and development of new products in these fields as well as the further development of products currently being manufactured.

◆

The American Welding Society has elected **Fred L. Plummer,** director of engineering of Hammond Iron Works, Warren, Pa., as president of the society for 1952-1953.

◆

Transicoil Corp., New York, has appointed **Dwight W. Bloser** as chief engineer for the manufacture of control motors, induction generators, gear trains and servo amplifiers. He was formerly senior engineer of the motor and synchro laboratory of Kearfott Co. Inc.

◆

David B. Parkinson has been named production engineering manager of Brush Development Co., Cleveland. Dr. Parkinson joined Brush in 1948 as department head of product engineering and before that time served with the Bell Telephone laboratories, developing telephone equipment and systems as well as antiaircraft and other gun directors.

◆

Mellon Institute of the University of Pittsburgh has announced the appointment of **Raymond H. Hartigan** as assistant director of research on the Institute's executive staff.

◆

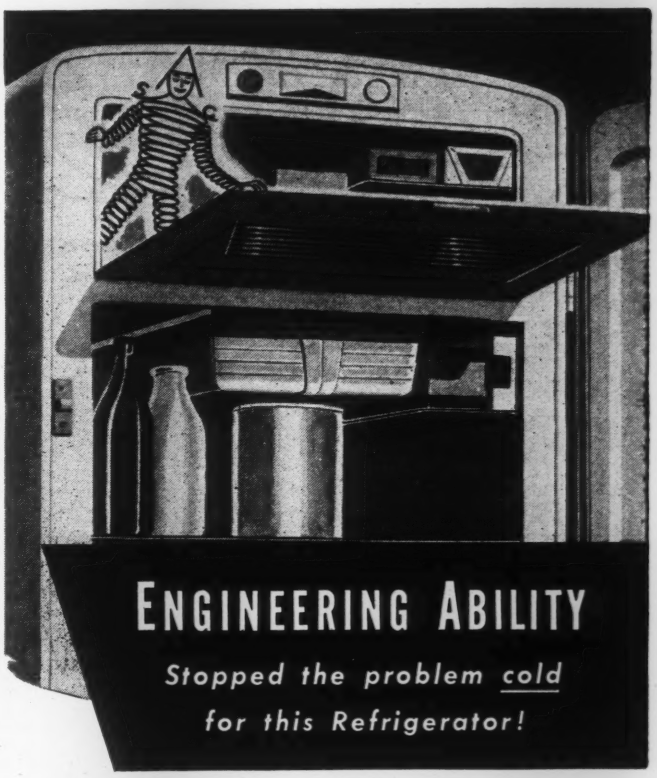
A veteran of 24 years with Westinghouse Electric Corp., **Ray H. Timmons** has been appointed manager of the Steam Div. at South Philadelphia, Pa. His most recent assignment was that of manufacturing manager for industrial products divisions, with headquarters in Pittsburgh.

◆

Richard P. Seelig has been named executive vice president of Chromalloy Corp., New York. He formerly served as a vice president of American Electro Metal Corp.

◆

Charles D. Greentree has been appointed manager of engineering of the General Engineering Laboratory of General Electric Co., Schenectady, N. Y. He succeeds **Martin A. Edwards,** whose appointment as man-



. . . with Springs by Automatic Spring Coiling Co.

The need was very specific—

"Give us a spring," this refrigerator manufacturer requested, "that can THINK . . . so to speak. We have an evaporator door to the cold chest compartment that must respond to the touch of a finger, swing open to a certain angle, and stop there. It should also be possible to close the door with a nudge of a food-burdened housewife's elbow."

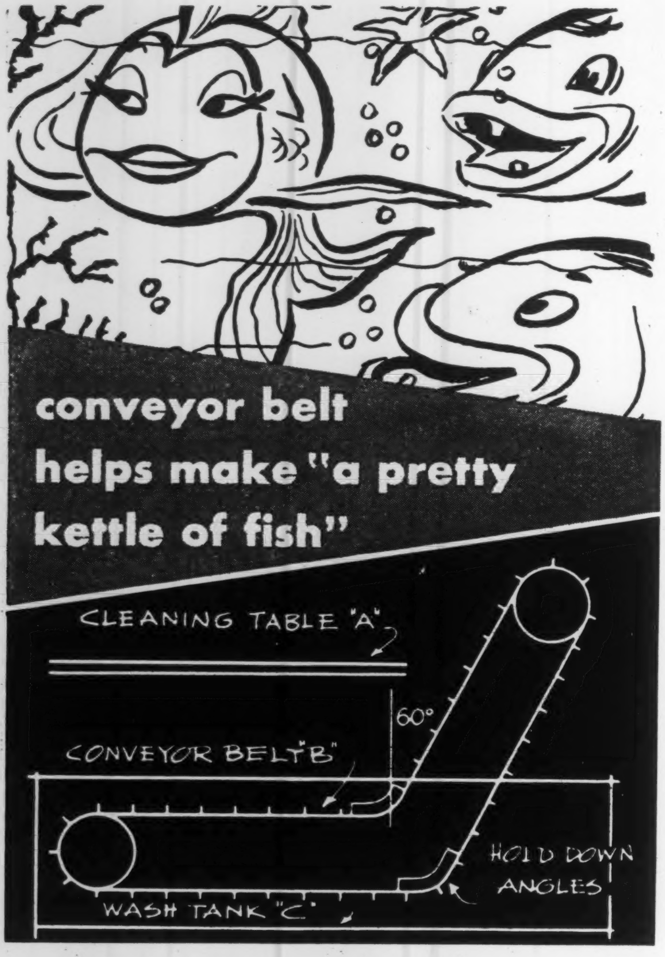
So . . . Automatic Spring Coiling Co. was called in and *Engineering Ability* came through!

The answer . . . calculated by our engineers was to design a spring with precisely the right *build-up,* with just the right combination of spring and wire diameter. In this way, not only would the spring do the required job—metering out its energy at the right rate—but also tolerances would be such that production could be handled with facility on our high speed equipment.

Put Automatic Spring Coiling Co. to work on *your* spring problem. See how members of our entire organization — consultants, designers, sample-makers, inspectors—swing into operation and *click.* Working as a well-integrated team with strict adherence to Quality Control we pledge ourselves to bring you the finest, most dependable springs to insure the successful and efficient performance of your product.

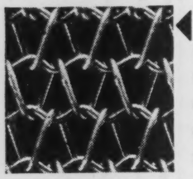
Our veteran consulting engineers are ready to survey your requirements without obligation. Please write.

AUTOMATIC SPRING COILING CO.
4043 West Thorndale Avenue
CHICAGO 30, ILLINOIS



No joke intended! This Cambridge Woven Wire Conveyor Belt carries cleaned fish through a wash tank to remove scales and scrap so the fish will present an attractive appearance on retail counters.

Cleaned fish are dropped from cleaning table A, onto the surface of conveyor belt B, passing through wash tank C. At the end of the tank hold down angles change the movement of the belt to a 60° incline. Stainless steel wire, used in weaving this belt, resists the corrosive attack of salt water in the wash tank, can be cleaned without damage by steam or by detergents added to the wash water.



◀In this application, BALANCED BELTING provides low original cost and controllable belt travel. ½" openings in belt weave permit free drainage of wash water and fish scraps. Angle cleats across the belt hold the fish during the movement up the incline.

This is a typical example of the many types of production and processing problems solved by the use of Cambridge Woven Wire Conveyor Belts. Cambridge belts can be constructed from any metal or alloy to a wide range of meshes and weaves. Don't fish around the next time you have a problem of combining movement with processing through heat, cold, liquids or corrosive agents . . . just call in your Cambridge field engineer for his experienced advice. Write direct or look under "Belting-Mechanical" in your classified telephone directory.

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CONVEYOR
BELTS

The Cambridge Wire Cloth Co.
Dept. N • Cambridge 12, Md.

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OFFICES IN PRINCIPAL INDUSTRIAL CITIES

FREE BELT MANUAL includes information on conveyor and conveyor-belt design, metallurgical data and belt maintenance. Write for your copy today.

ager of engineering of the X-ray department in Milwaukee was announced recently. **Dagfin H. Hanson** replaces Mr. Greentree as manager of the laboratory's development manufacturing and plant services.

◆

Beatty Machine and Mfg. Co., Hammond, Ind., has named **John Borkert** as chief engineer.

◆

Chief engineer since 1946, **Donald E. McGuire** succeeds **Julius A. Clauss,** who has retired, as vice president in charge of engineering for Great Lakes Steel Corp., Ecorse, Mich.

◆

The Gerotor May Corp., Baltimore, has announced the election of **B. Frank Quintilian** as vice president in charge of engineering. He has been associated with the company for 20 years and has served as chief engineer for several years.

◆

R. J. Sigafoo was recently appointed chief engineer of the bus division of Flxible Co., Loudonville, O. He was formerly engineer at Twin Coach Co. and engineering assistant to the president.

◆

Having joined the company in 1937, **James H. Taylor** has been appointed chief electrical engineer of United Engineering and Foundry Co., Pittsburgh, succeeding **Robert H. Ellis,** who was named consultant electrical engineer.

◆

H. L. Weinberg, new director of engineering for American Locomotive Co., New York will be in charge of product development and engineering in the locomotive division with headquarters at Schenectady, N. Y.

◆

Formerly director of engineering for International Harvester Co., Chicago, **Arnold E. W. Johnson** has been elected a vice president.

◆

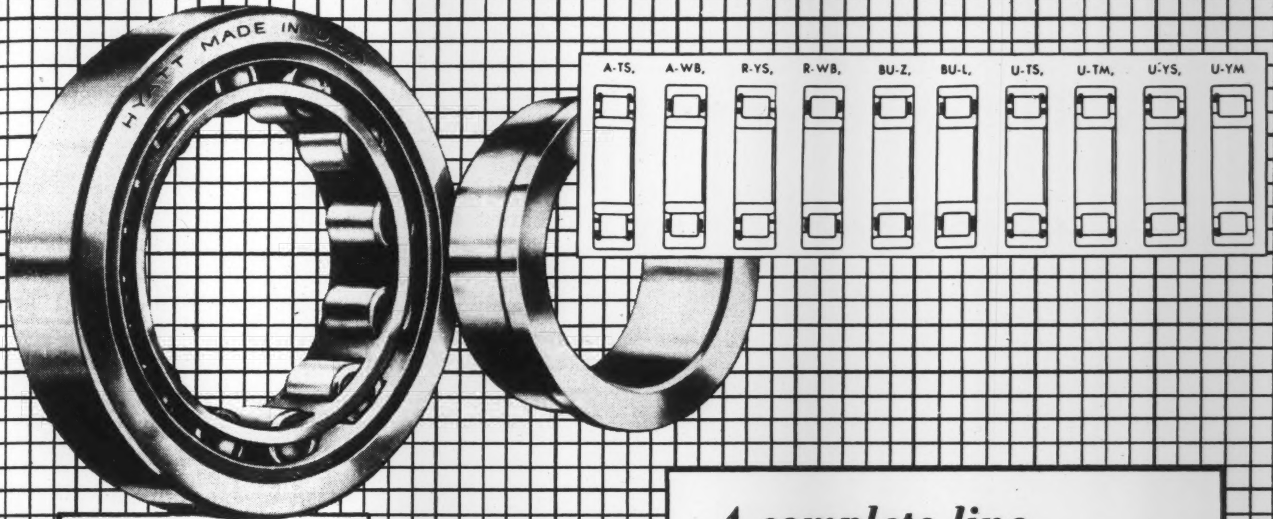
Chief engineer since November 1951, **Hall Young Kaighin** has been named director of product development for Lippincott & Margulies, New York industrial designers.

◆

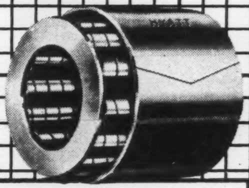
Oliver United Filters Inc., New York, has appointed **Dwight Richards** to the post of director of engineering.

◆

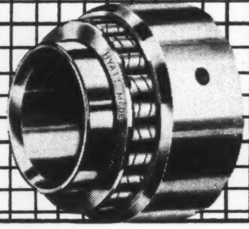
The Royal New Zealand Aero Club Musick Memorial Trophy was awarded recently to two American engineers, **John E. Lindberg Jr.** and **James W. Wheeler** for their joint development of the Sperry engine analyzer, an electronic device that detects, locates and identifies detailed ignition and mechanical diffi-


HYATT MADE IN U.S.A.
A-TS.
A-WB.
R-YS.
R-WB.
BU-Z.
BU-L.
U-TS.
U-TM.
U-YS.
U-YM

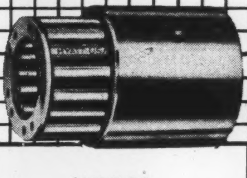
HY-LOAD SERIES



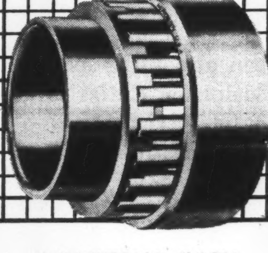
WOUND ROLLER SERIES
(Split Outer Races)



WOUND ROLLER SERIES
(Solid Races)



90,000 SERIES



INDUSTRIAL INCH SERIES

A complete line to choose from

When you are faced with a design problem involving bearings, you can save yourself a lot of time by consulting your Hyatt Catalog immediately.

Because of the wide range of sizes and bearing types included in the Hyatt line you can usually find just the right bearing for each set of operating conditions.

If you need technical help in your selection of bearings call upon our engineering staff for expert advice. We have been manufacturing bearings and applying them to our customers' products for so long that many conditions which might be strange to you are quite familiar to us.

For complete information about Hyatt Roller Bearings look to our Catalog No. 150 or for information about particular bearings or their application write to Hyatt Bearings Division, General Motors Corporation, Harrison, New Jersey.

HYATT ROLLER BEARINGS

HARTWELL

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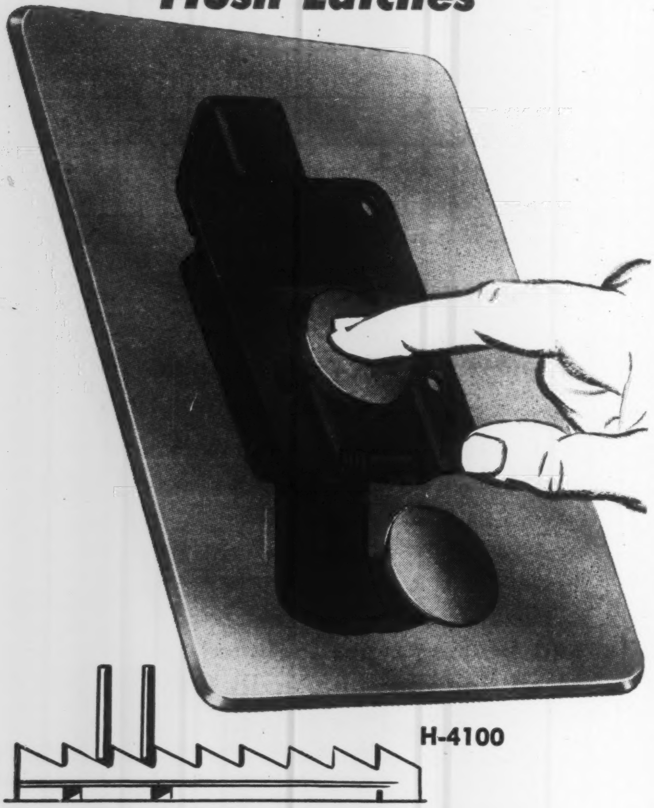
Push Button Flush Latches



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Go Modern with HARTWELL
Flush—Self-Closing—Easy to Operate—Simple to Install

Latch is operated by a natural rotation of the hand for push-and-lift positive action. As the forward button is depressed, the rear button raises, providing a sturdy grip for opening the door.

Your need for efficiency and economy today finds a powerful ally in the *Flush Latch* and *Hinge* talents of HARTWELL. Here is the latest *"push button"* method for solving your *flush* latching problems.

Write for engineering specifications and counsel.

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COMPANY
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9035 Venice Boulevard, Los Angeles 34, California

culties in aircraft power plants during actual operation. Mr. Wheeler is head of the engine instrument department of Sperry Gyroscope Co., and Mr. Lindberg is president of the Lindberg Engineering Co.

◆

Engineering Research Associates Inc., St. Paul, has appointed **Carl E. Swanson** to the position of senior scientist to supervise the firm's St. Paul division special projects activities. Projects under his direction will include work on automatic industrial process control systems, magnetic recording techniques and systems and development of communications equipment.

◆

The Permutit Co., New York, has appointed **Felix W. Saco** to the position of mechanical development engineer.

◆

Engineering and Research Corp., Riverdale, Md., has appointed **Eric Ledin** as group engineer for cockpit design and **James E. Hays** as group engineer for structures in its Flightronic flight simulator division.

◆

Arthur D. Little Inc., Cambridge, Mass., has appointed **Frank E. Maddocks Jr.** to its engineering physics and special devices group and **Donald E. Key** to its mechanical division.

◆

Newly appointed staff engineer of Visi-trol Engineering Co., Detroit, **Sam R. Read** will serve as a consultant on processing, planning and design of complete production lines for automotive and aircraft engines, automatic transmissions and related components.

◆

T. E. Schroeder has joined Sargeant & Wilbur Inc., Pawtucket, R. I., as chief engineer of the heavy furnace division.

◆

John Davies has been appointed assistant chief engineer of the axle division of Eaton Mfg. Co., Cleveland, replacing the late **Harry H. Hooker.** At the same time **Chester D. Christie** was appointed staff engineer.

◆

To be in charge of the mass spectrometer group of the company's engineering department, **Gardner P. Wilson** has joined Consolidated Engineering Corp. as a senior development engineer.

◆

Professor S. M. Marco has been named chairman of the department of mechanical engineering at Ohio State University, succeeding **Professor Aubrey I. Brown,** who relinquished the chairmanship in order to devote his time to teaching.

Need Impact Strength?

TRIPLE SHOCK RESISTANCE

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ALUMINUM ALLOY

For the first time....all vital properties in one alloy, as-cast.

As-cast, with *no heat treatment* or age hardening, standard sand cast 90° V-notch test specimens of ALMAG 35 produce average Charpy Impact results of 10.47 foot pounds . . . nearly triple the impact resistance of heat treated alloys previously recommended.

Shock resistance is only one of ALMAG 35's standout qualities; it also possesses the highest, most stable combination of strength, ductility, corrosion resistance, and dimensional stability of any *as-cast* aluminum alloy.

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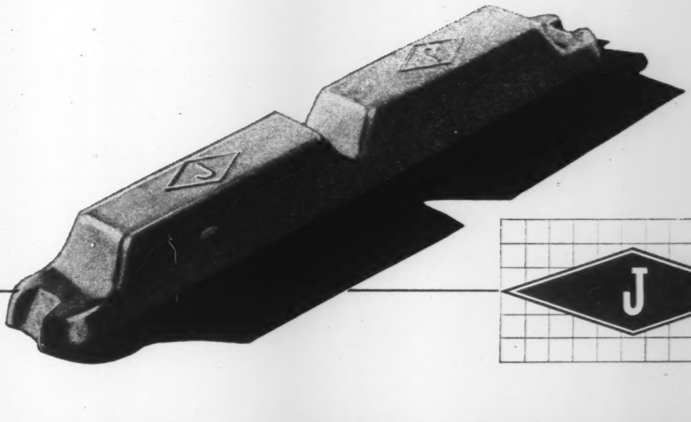
MIL-A-10935-6-7



U.S. Patent No. 2564044.

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AURORA P. O. BOX 230 **ILLINOIS**

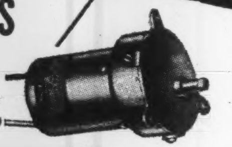
DESIGNING FOR DEFENSE?

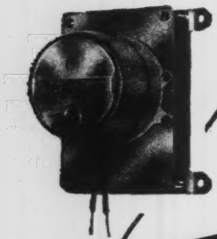
UTILIZE COMPACT

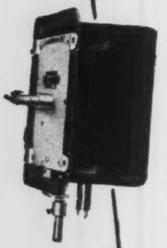
SYNCHRON
TRADE MARK

TIMING MOTORS
TIMING MACHINES
CLOCK MOVEMENTS
D. C. MOTORS

TIMING MOTORS







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SYNCHRON synchronous motors meet your requirements for compact power. Pulls up to 8 oz. direct load continuously at 1 R.P.M. Gear trains can be furnished to convert to any speed. Unusual actions can be incorporated in movement. Our engineers will be glad to work with you in developing motors for special applications.

Hansen D.C. motors powered servo units which won Army-Navy E. Used also in aircraft instruments and radio control mechanisms.

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MD

THE ENGINEER'S Library

Recent Books

Numerical Methods in Engineering. *By Mario G. Salvadori, associate professor of civil engineering, and Melvin L. Baron, research associate, Columbia University;* 272 *pages, 5½ by 8½ inches, clothbound; published by Prentice-Hall Inc., New York; available from* MACHINE DESIGN, $6.65 *postpaid.*

Elementary techniques in the application of numerical methods to the solution of technical problems are the subject of this textbook. Aim of the book is to fill the gap between a knowledge of theoretical mathematics and the technique of solving physical problems by mathematical methods. A knowledge of calculus and a familiarity with differential equations is assumed. Techniques presented have been selected on the basis of simplicity and efficiency and can usually be applied to electric desk calculators or, in many cases, slide rules.

Comprised of five chapters, the text material covers practical solution of algebraic and transcendental equations; finite differences and their applications; numerical integration of initial value problems; numerical integration of ordinary boundary value problems; and numerical solution of partial differential equations. Both numerical exercises and applied problems, many with answers, have been included for each chapter.

Electrical Reference. *By E. S. Lincoln, consulting engineer;* 1,758 *pages,* 8¼ *by* 11 *inches, clothbound; available from Electrical Modernization Bureau Inc.,* 110 *Mamaroneck Ave., White Plains, N. Y.,* $25.00.

Made up in catalog form this second edition deals with available industrial electrical equipment. Changes in the original version, published in 1941, include additional technical data and improved editorial makeup. Text material is mainly devoted to standard equipment and ratings and covers industrial wiring systems, utilization equipment (motors, lighting, welding etc.), departmental equipment (inspection, maintenance, testing, etc.), and electrical instruments and measurements. Well illustrated with tables, diagrams and photographs, the book also contains pertinent National Electric Code Regulations and NEMA and ASA standards.

Performance of Lubricating Oils. *By H. H. Zuidema;* 187 *pages, 6 by 9 inches, clothbound; published by Reinhold Publishing Corp., New York; available from* MACHINE DESIGN, $5.00 *postpaid.*

In this treatment of lubricating oils, the subject

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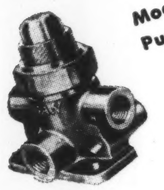

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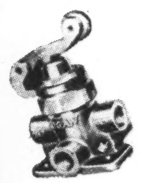

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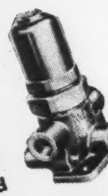
Cam operated



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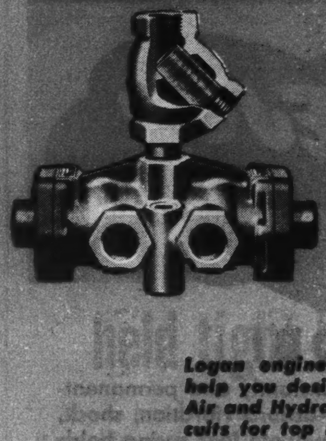

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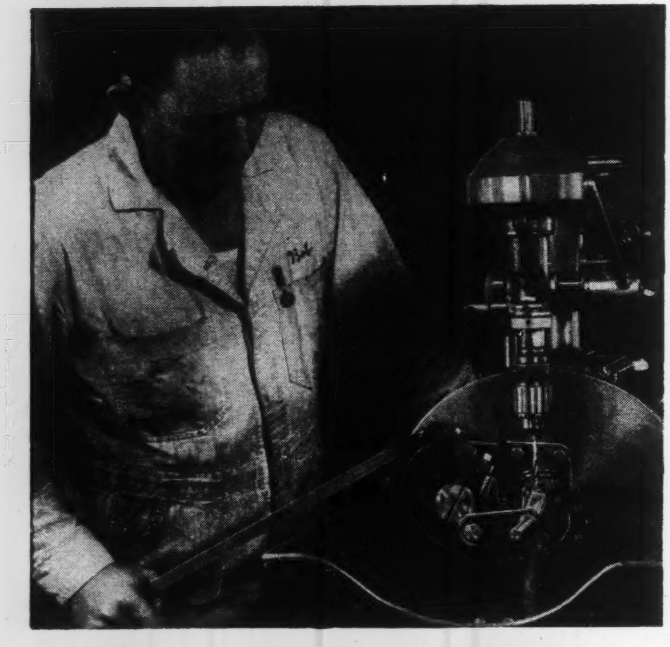

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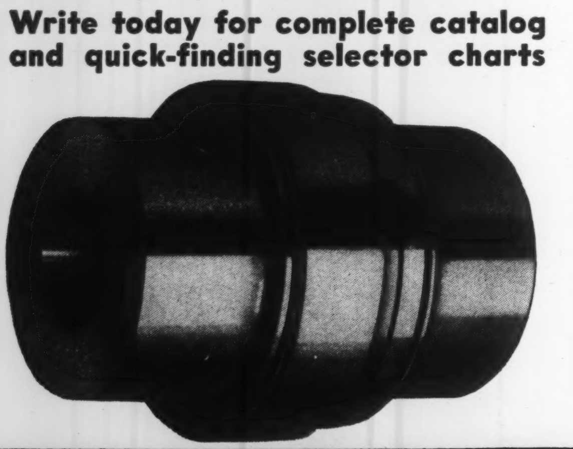

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is approached on the basis of performance characteristics—oxidation, bearing corrosion, wear, etc.— common to all applications. Most of the information has been taken from work on lubricants for automotive equipment; however, conclusions should also apply to related problems.

The introductory chapter discusses the process of lubrication and is followed by a chapter on rheology. Succeeding chapters cover oxidation; bearing corrosion; sludge and lacquer deposition; emulsification and foaming; and wear. In the concluding chapter on manufacturing methods, the effect of each process step upon the performance characteristics of the resulting product is explained.

Writing the Technical Report. *By J. Raleigh Nelson, professor emeritus of English, College of Engineering, University of Michigan; 374 pages, 6 by 9 inches, clothbound; published by McGraw-Hill Book Co. Inc., New York; available from* MACHINE DESIGN, $4.50 *postpaid.*

As the author defines it, a report is "a communication of information or counsel which is desired and which will be used by some one for some particular end." Thus, a report must be "designed" to meet all conditions under which it will be used. In this third edition, as in the previous versions, emphasis is placed on technical report design or planning. Text material is less concerned with incidentals of form and convention than with basic principles and procedures. Topics covered include design and composition of the report; directions for setting-up long and short-form reports; a systematic procedure for the critical examination of a report; and a summary of basic principles. The final section of the book is made up as a reference manual on the fundamentals of report writing.

Corrosion Testing Procedures. *By F. A. Champion;* 379 *pages, 5½ by 8½ inches, clothbound; published by John Wiley & Sons Inc., New York; available from* MACHINE DESIGN, $6.25 *postpaid.*

Information presented in this book is directed mainly at those concerned with practical problems in the corrosion of metals in service and the production of metal of adequate corrosion resistance. The text has been divided into stages which deal with the choice and preparation of metal and corrosive; exposure of the metal; preparatory cleaning of specimens; examination of specimen or corrosive for effects; and the expression and interpretation of results. Various alternative procedures for each of the stages are also discussed.

Mechanics of the Gyroscope. *By Richard F. Deimel, professor of mechanical engineering, Stevens Institute of Technology; 208 pages, 5½ by 8 inches; available from Dover Publications Inc.,* 1780 *Broadway, New York* 19, *N. Y.; $1.60 paperbound; $3.00 clothbound.*

An elementary general treatment of the dynamics of rotation makes up the subject matter of this second edition textbook. The first three chapters deal with fundamental theory and briefly cover plane motion, motion in space, and dynamic laws. In the remaining seven chapters rotational phenomena and the behavior of typical gyroscopic apparatus are discussed.

New Standards

Mounting Dimensions of Lubricating and Coolant Pumps for Machine Tools. *ASA B*5.28-1952; 11 *pages,* 8½ *by* 11 *inches, paperbound; copies available from American Society of Mechanical Engineers, Order Dept.,* 29 *West* 39*th St., New York* 18, *N. Y.*; $1.00.

This new standard covers two types of mountings: (1) pumps mounted directly to machine tools and (2) pumps mounted to motors which are attached to the machine tools. A special committee from the National Electrical Manufacturers Association worked with the ASA committee in evolving the standard which is based on a memorandum from the National Machine Tool Builder's Association to the American Society of Mechanical Engineers.

Preferred Thicknesses for Uncoated Thin Flat Metals. *ASA B*32.1-1952; 5 *pages,* 8½ *by* 11 *inches, paperbound; copies available from American Society of Mechanical Engineers,* 29 *West* 39*th St., New York* 18, *N. Y.*, $1.00.

This standard supersedes ASA B32.1-1941, "Wire and Sheet Metal Gages." In addition to the title change, the original 20-series of preferred numbers has been expanded to a 40-series and reference is made to an 80-series which can be used.

Gas Transmission and Distribution Piping Systems. *ASA B*31.1.8-1952; 34 *pages,* 8½ *by* 11 *inches, paperbound; copies available from American Society of Mechanical Engineers, Order Department,* 29 *West* 39*th St., New York* 18, *N. Y.*, $1.25.

Minimum requirements for the design, fabrication, installation, testing and operation of piping systems for conveying substantially noncorrosive combustible gases are prescribed in this new section of the American Standard Code for pressure piping. Work under progress indicates that this section will shortly be replaced by a substantially revised version.

Specifications for Copper and Copper-Alloy Welding Rods. *ASTM Designation B* 259-52 *T, AWS Designation A* 5.7-52 *T;* 13 *pages,* 6 *by* 9 *inches, paperbound; copies available from either American Welding Society,* 33 *West* 39*th St., New York* 18, *N. Y. or American Society for Testing Materials,* 1916 *Race St., Philadelphia* 3, *Pa.;* 40 *cents.*

Issued jointly by ASTM and AWS, these specifications for filler metal cover copper and copper-alloy welding rods for use with oxyacetylene, carbon-arc and inert-gas metal-arc (nonconsumable electrode) welding. An appendix to aid in the selection of the appropriate welding rod is included.

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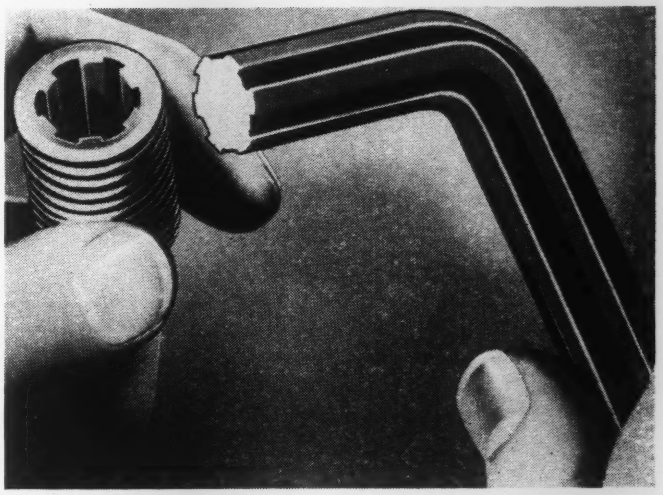

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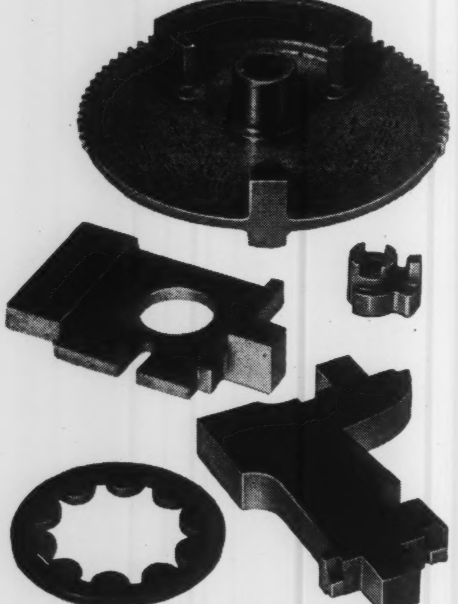

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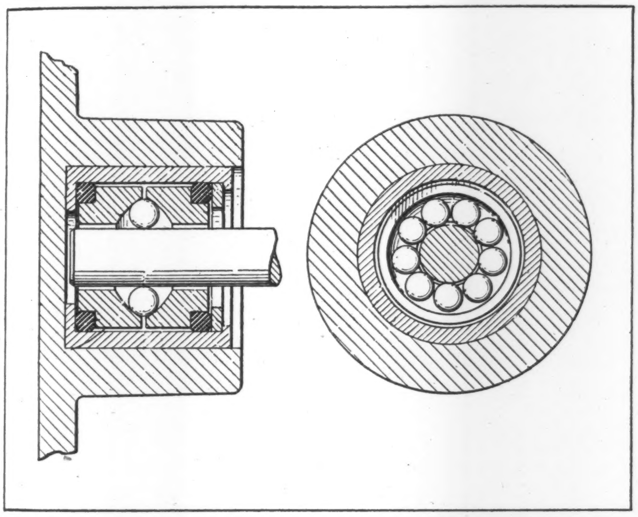
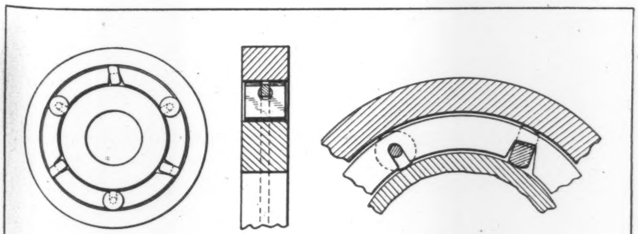
NOTEWORTHY Patents

Ball bearing noise is claimed to be practically eliminated without the necessity of heavy preload in a lightweight self-aligning bearing that utilizes the shaft itself as an inner race. Outer race of the bearing is split in halves, each of which is supported by an O-ring inside a cartridge mounting. Cushion effect of the rings takes up radial looseness in the bearing, permits the shaft to operate simultaneously at a slight angle and to float axially, isolates shaft vibration, and protects the bearing against shock loads. Patent 2,588,636 assigned to Crise Mfg. Co. by Theodore Y. Korsgren.



Structural simplicity is achieved in a combination roller bearing and sprag-type overrunning clutch through grooved rollers and sprags designed to permit the use of a single notched carrier ring for both sets of elements. Notches provided for the sprags are cut at angles which assure instant engagement or release of the sprags when direction of rotation of the carrier is reversed. This simplified arrangement is said to make practical the manufacture



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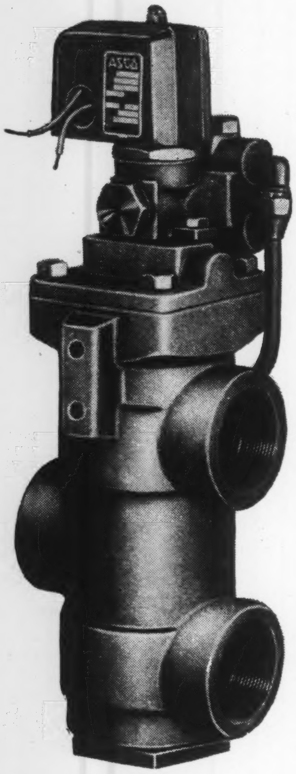

We recommend this valve for controlling equipment where pressure must be alternately applied and exhausted as, for example, with diaphragm motor valves, air or hydraulic cylinders, etc. Classed as Bulletin 8331 ASCO Valves, here are a few specifications: pipe sizes 1, 1¼, 1½ and 2 inches. Maximum pressure 125 to 250 pounds; minimum pressure 10 to 20 pounds. Suitable for handling air, water, gas, oil and other non-corrosive gases or liquids up to 180°F.

Since the automatic control of any alternating application and release of pressure is so important for efficient operation, we suggest that you bring your problems to the attention of our engineers. Designing just such controls has been our business for nearly forty years. If Bulletin 8331 Valve doesn't seem to fit your requirements, we have many other types—all in the broad class of automatic control units. Or, if necessary, we shall be glad to design a new type of valve to fit your special needs.

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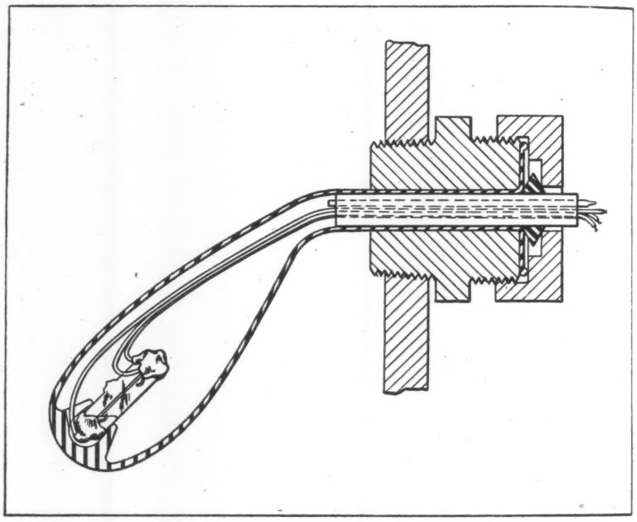
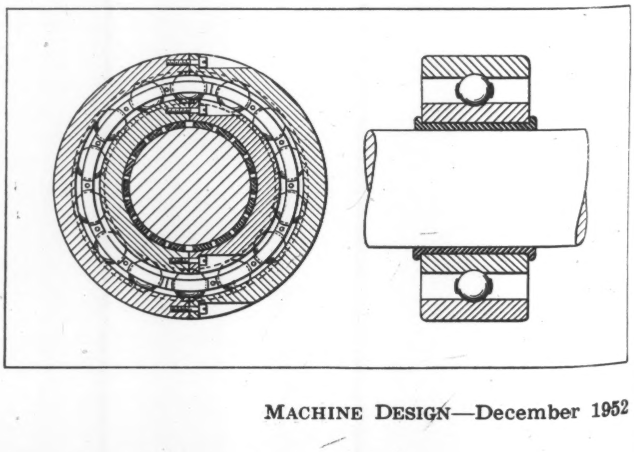
of much smaller combined bearing and one-way clutch units than heretofore available. Patent 2,598,864 assigned to Borg-Warner Corp. by Harold H. Turner.

SELF-DESCALING ACTION is achieved in a nonmechanical float control switch by utilizing a flexible and expansible bag member as the float. Anchored by its neck to the inside wall of a pressure vessel, the bag carries within itself a mercury switch that operates with rise and fall of the bag as determined by fluid level. Normal pressure variations within the fluid vessel cause the bag to expand or contract, thus prohibiting the formation of scale and subsequent malfunctioning control because of increased float mass. Patent 2,588,667 assigned to Minneapolis-Honeywell Regulator Co. by Warren S. Stutzman.



RESILIENT BEARING LINER permits mounting a split antifriction bearing securely even though the shaft diameter may vary considerably from a specified nominal dimension. Voids are provided in both halves of the liner to equalize flow of the resilient material throughout the clamped area. This prevents



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Bronze backs lined with tin-base babbitt; cast iron backs lined with tin- or lead-base babbitt; steel backs lined with copper-lead alloys, babbitt or leaded bronze. Plain or flanged, half or full-round. All-bronze piston pin bushings.

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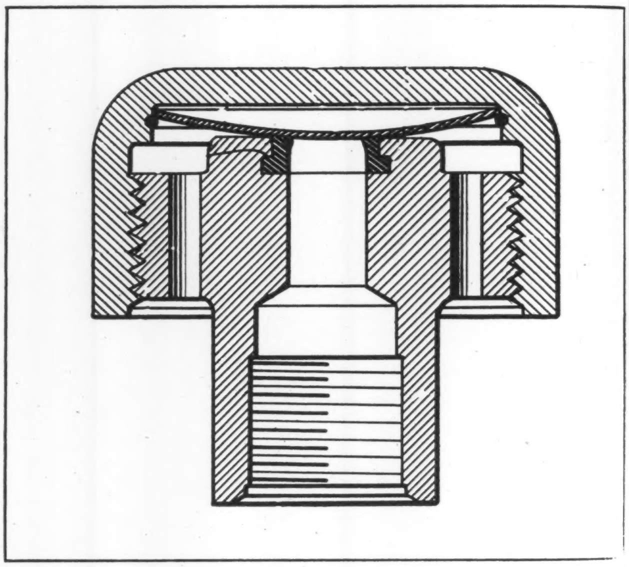
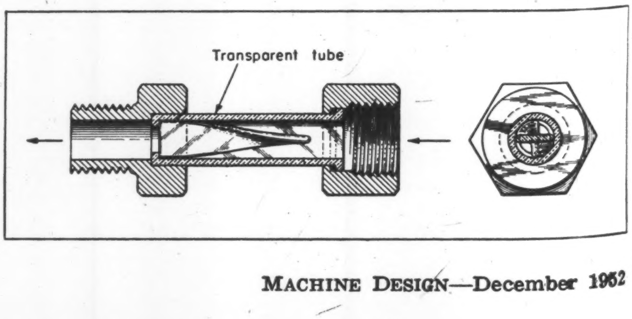
distortion of the inner race when drawn tight to compress the liner. The liner also absorbs and insulates the bearing from radial and transverse shocks and thus minimizes or eliminates damage to the assembly. Patent 2,608,451 assigned to Split Ballbearing Corp. by Winslow S. Pierce, Jr.

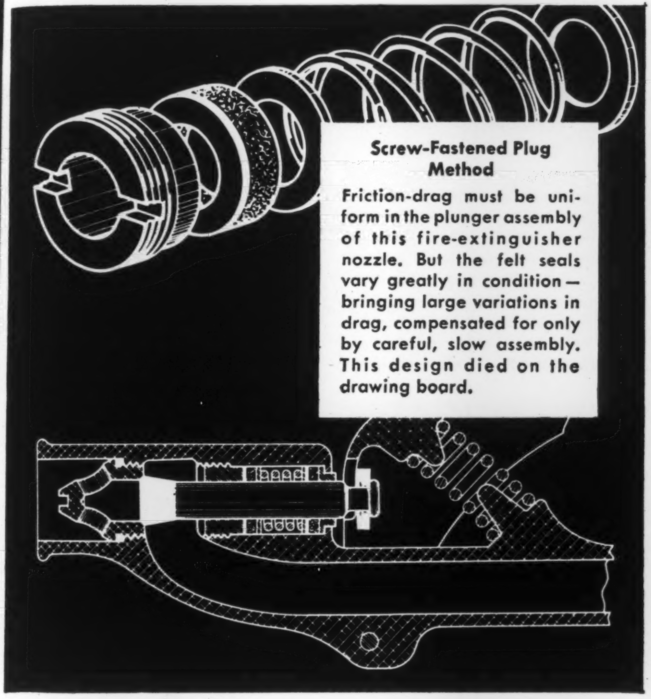
INSTANTANEOUS RELIEF at preset pressure is provided by a fluid release valve in which a simple dished metal diaphragm is utilized as the valving element. Wire-ring retained in a threaded cap, the diaphragm thrusts against a lipped resilient ring held in the discharge orifice of the valve seat, sealing drop-tight. At predetermined pressure, according to initial tightness of the cap, the diaphragm pops into a flat condition allowing maximum discharge instantaneously. Patent 2,585,863 assigned to the Maytag Co. by Thomas R. Smith.



VISUAL FLOW INDICATION in low-pressure oil filter discharge lines is registered by a simple in-the-line device having a single moving part. Until such time as the filter becomes plugged, flow through a transparent tube of the indicator causes a spiral vane inside the tube to rotate. Guided by the inside wall of the transparent tube, the outer edge of the vane

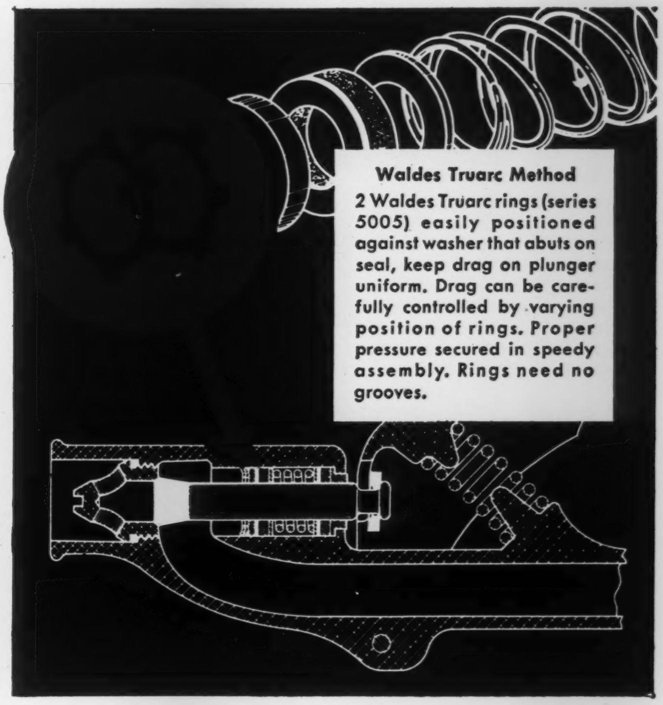


2 Truarc self-locking rings replace threaded plugs. Save 6¢ per unit, speed assembly by 140%.



Screw-Fastened Plug Method

Friction-drag must be uniform in the plunger assembly of this fire-extinguisher nozzle. But the felt seals vary greatly in condition — bringing large variations in drag, compensated for only by careful, slow assembly. This design died on the drawing board.



Waldes Truarc Method

2 Waldes Truarc rings (series 5005) easily positioned against washer that abuts on seal, keep drag on plunger uniform. Drag can be carefully controlled by varying position of rings. Proper pressure secured in speedy assembly. Rings need no grooves.

Ansul Chemical Company's new watertight precision nozzle for their dry chemical fire extinguisher replaces conventional stainless steel plug with two Waldes Truarc Self-Locking Retaining Rings and washer. Rings hold entire nozzle packing securely in place — keep friction drag of plunger uniform. Adjustable in final assembly, Truarc rings speed production from 25 to 60 units per hour. They save 6¢ per unit in overall costs, 1/8" in length.

Redesign with Waldes Truarc Rings and you, too, will save on assembly, time, improve product performance, facilitate easier servicing of whatever you make.

Wherever you use machined shoulders, bolts, snap rings, cotter pins, there's a Waldes Truarc Retaining Ring designed to do a better job of holding parts together. They're precision-engineered . . . quick and easy to assemble and disassemble. They give a never-failing grip. Find out what Truarc Rings can do for you. Send your blueprints to Waldes Truarc engineers for individual attention, without obligation.

WALDES TRUARC RINGS MADE THESE SAVINGS POSSIBLE—

Discarded Design		**Truarc Design**	
Parts:	**Cost Per Unit**	**Parts:**	**Cost Per Unit**
threaded stainless steel plug	$0.0675	2 rings	$0.0146
Direct Labor	$0.0350	1 washer	$0.0280
	$0.1025		$0.0426

Total savings per unit with Truarc Rings $.0599

For precision internal grooving and undercutting . . . Waldes Truarc Internal Grooving Tool.

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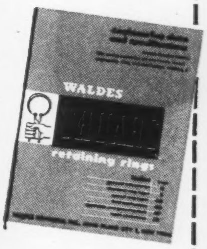

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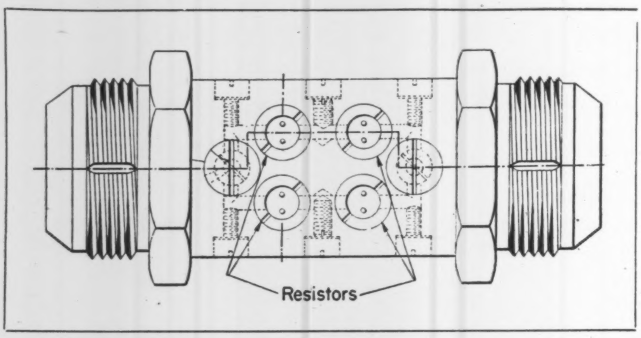
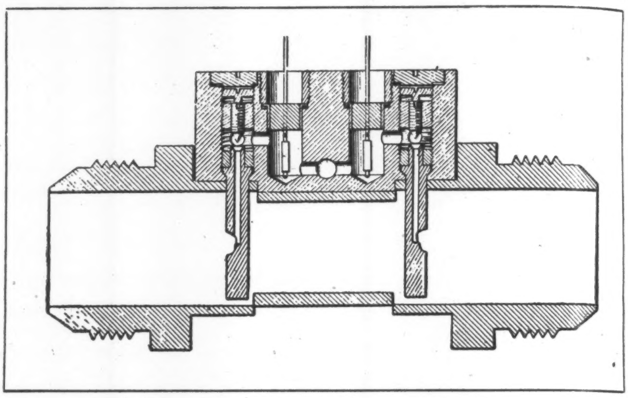
may be observed, even though the fluid itself may not be transparent. Patent 2,599,201 granted to Robert Rubenstein and Sidney I. Groban.

PULSING PRESSURE INFLUENCE is damped effectively in a thermoelectric flowmeter by virtue of its inherent thermal lag of response. Flow rates of gases or liquids are determined by the effect of forced convective cooling on heated resistors of a Wheatstone bridge circuit. The resistors are located in a by-pass channel of the meter. Cooling proportional to change in flow rate causes a corresponding change in electrical resistance of the thermally sensitive filaments which in turn control an indicating meter. The filaments may have a positive or negative temperature coefficient and may be insulated or noninsulated depending on the nature of the fluid and the degree of damping desired. Patent 2,591,195 assigned to Breeze Corp. Inc. by Michael A. Picciano.





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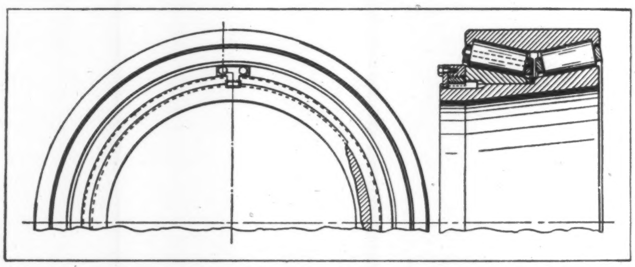

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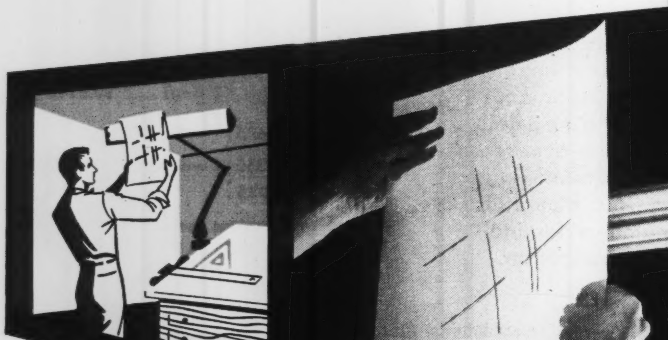

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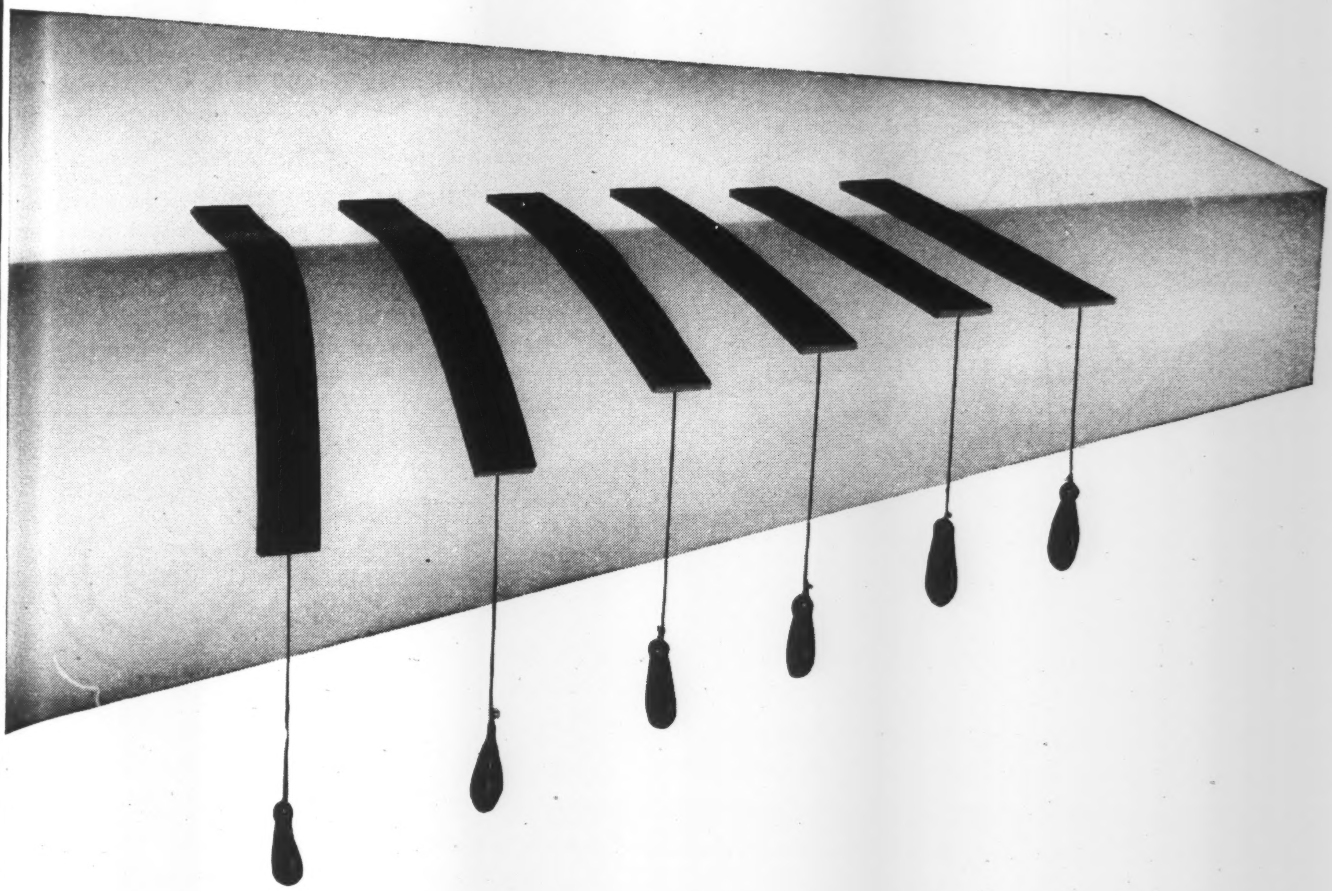
For flexibility or rigidity…



it's ENRUP. . . U. S. Rubber's great plastic

Between the extreme elasticity of soft rubber (the strip at extreme left) and the rigidity of hard rubber (strip at extreme right) are four strips of Enrup. Note the varying degrees of flexibility, making Enrup a true bridge between hard and soft rubber.

This plastic has excellent dielectrical properties and unusual resistance to chemicals and abrasion. It can be molded to close tolerances, eliminating the need for expensive finishing operations. It can be made into almost any shape or form, simple or complex.

Enrup is molded and fabricated exclusively by United States Rubber Company engineers. It may be exactly what you have been looking for to make your product stronger, more efficient, less expensive. For more information, write to address below.

PRODUCT OF

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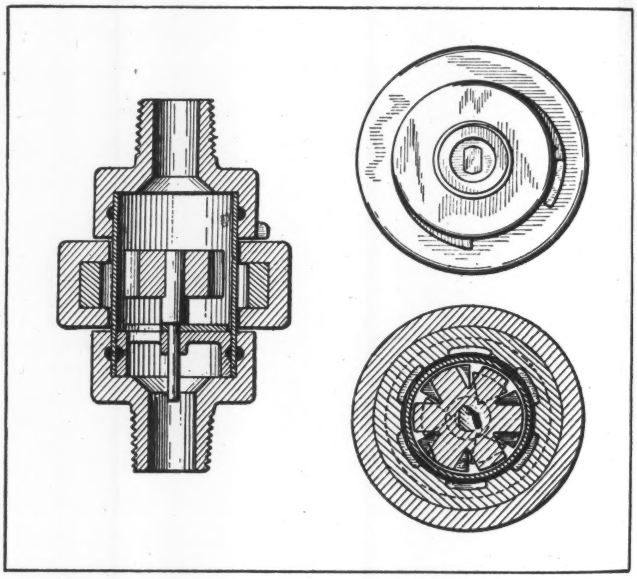
SERVING THROUGH SCIENCE

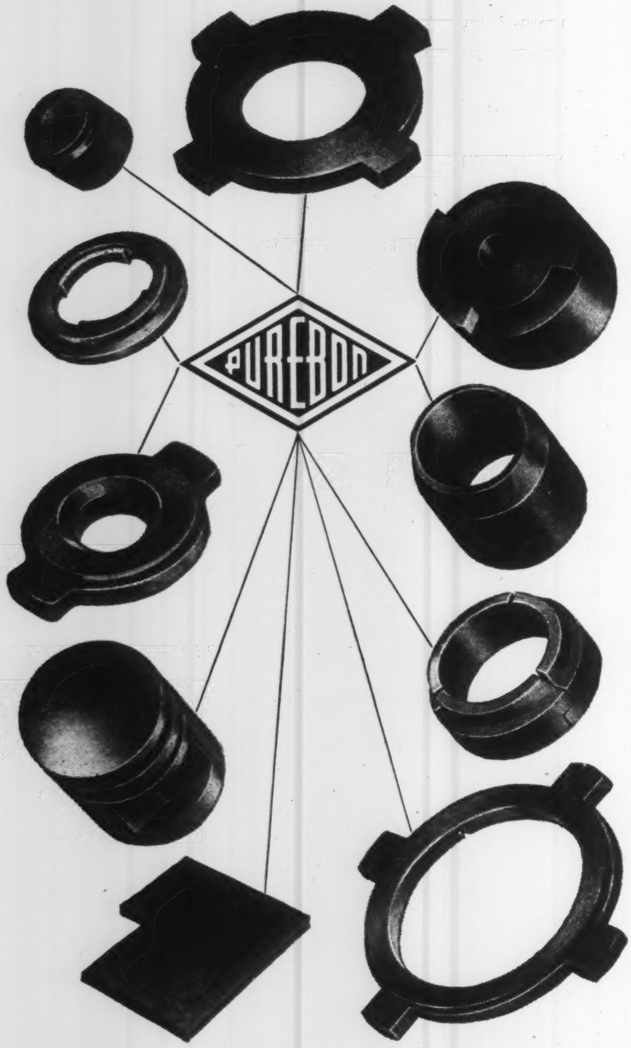
UNITED STATES RUBBER COMPANY
MECHANICAL GOODS DIVISION · ROCKEFELLER CENTER, NEW YORK 20, N. Y.

clearance in the bearing at assembly. The separable cone locates against a shimmed thrust shoulder and is drawn tight by a nut which threads over a split retaining ring snapped into a keeper groove in the main inner cone. The split ring and separable cone are keyed to the inner cone by a gibbed key to prevent relative rotation of these parts. A T-shaped key screwed to the outer face of the adjusting nut engages the keyway of the inner cone to lock the bearing adjustment. Patent 2,606,799 assigned to the Timken Roller Bearing Co. by Samson M. Weckstein.

AXIALLY OFFSET MAGNETS in a stemless and, therefore, packless disk type flow control valve provide pull for holding the valve disk on its seat. One magnet, inside the thin-walled valve body, is similar to a miniature armature and is keyed to a notched valve disk. The outer or adjusting magnet is ring shaped with internal poles alternately matching those of the armature. Should the armature fail to respond to normal rotation of the adjusting ring, further rotation aligns like poles of the inner and outer members and magnetic repulsion frees the valve by lifting it from the seat. Patent 2,589,188 assigned to Crane Co. by Edmond P. De Craene and Edward G. Schmidt.



LONGEST PATENT on record, assigned to the Bell Telephone Laboratories, is No. 2,585,904 covering a new automatic telephone system. This unusually large patent actually resembles a good sized book and weighs approximately 2¾ lb. Circuit diagrams alone make up 238 pages of the patent. Additionally, 109 pages of text explain fully the operation of the entire system which is the invention of Aloysius J. Busch.



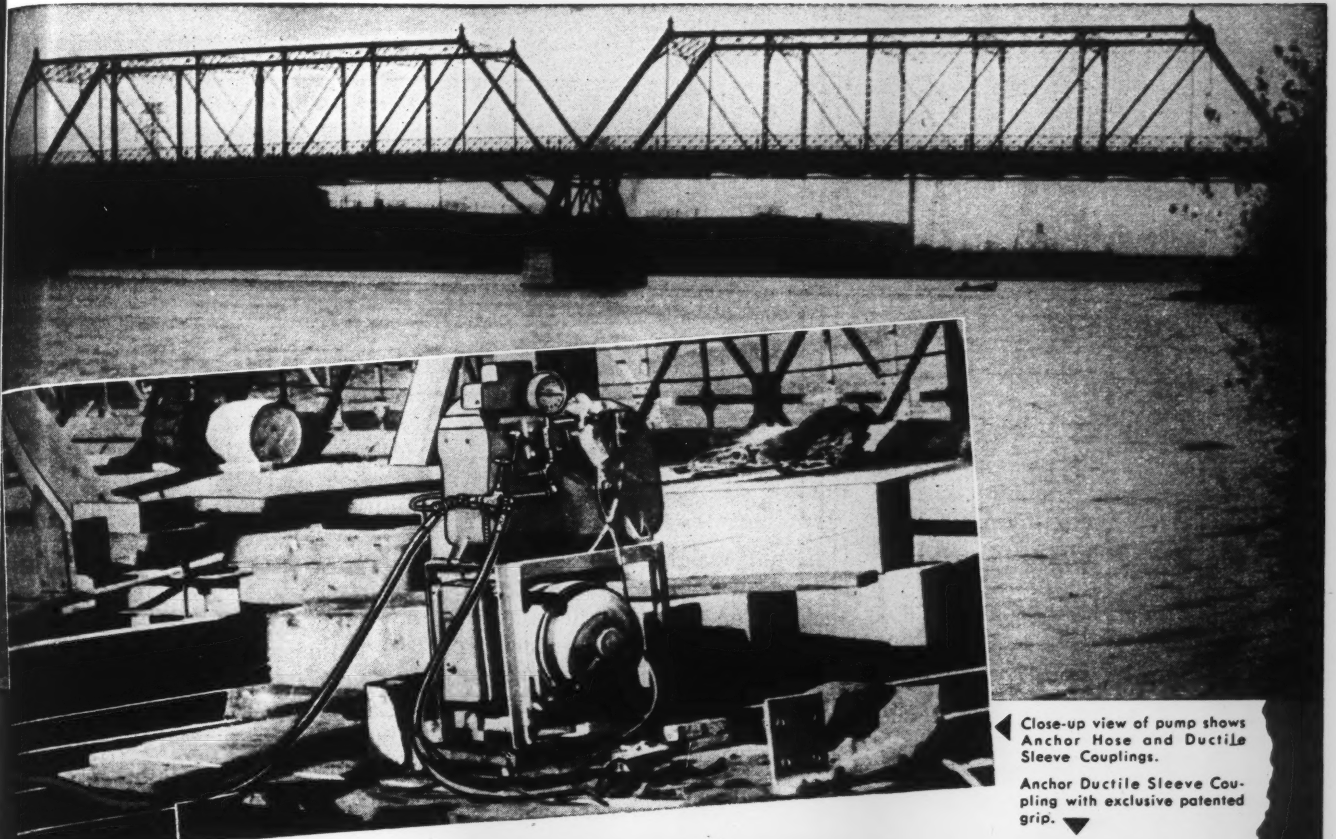
Purebon

SOLVES MANY PROBLEMS
caused by sliding or rotating parts which are DIFFICULT OR IMPOSSIBLE TO LUBRICATE

A constantly increasing stream of problems are facing engineers and designers today involving sliding or rotating parts where lubrication is difficult or impossible. For such applications, Purebon, the mechanical carbon, is often the ideal answer. Typical applications are seal rings, bearings, pistons, piston rings, pump vanes, valve seats, meter discs, and a host of similar items. Purebon comes in a wide variety of grades. It is strong, tough, readily machinable and in many cases can be molded directly to size.

Bulletin No. 52 tells the complete story of Purebon.
Write for your copy today.

PURE CARBON CO., INC.
446 HALL AVE. ST. MARYS, PA.



Close-up view of pump shows Anchor Hose and Ductile Sleeve Couplings.

Anchor Ductile Sleeve Coupling with exclusive patented grip.

Bridge lifting job handled easily—

with high-pressure ANCHOR hose and ductile sleeve couplings

MINNEAPOLIS . . . Here's a difficult job recently performed on the Broadway Avenue Bridge. Four spans across the upper Mississippi, each weighing approximately 250 tons, were raised to provide 19 ft. additional clearance at one side of the river for the passage of boats and sloped to the existing level on the other side. Anchor Hose and Ductile Sleeve Couplings, well-known for dependability and safety, were used for transmitting the required high hydraulic pressures to the twenty 4" jacks under each span. The use of hydraulic hose and the principle of hydraulic lifting made it possible to do this unusual job.

Tough jobs like this point up the superiority of Anchor factory-assembled couplings and hose. The positive seal eliminates leakage even under extreme pressures. The exclusive, patented Anchor grip makes the coupling virtually a part of the steel reinforcing wire of the hose — prevents blow-offs.

These complete high-pressure hose assemblies are exactly tailored to your particular job. They assure a wide safety margin and fewer hydraulic equipment breakdowns.

Typical uses of Anchor's complete range of flexible hose lines and couplings include high-pressure riveting, road machinery, coal mining equipment, machine tool applications, farm tractors, railroads, oil field machinery, and lubrication.

Find out how these time-, trouble-, and money-saving hose assemblies can improve your product — *Attach coupon to your letterhead and mail TODAY!*

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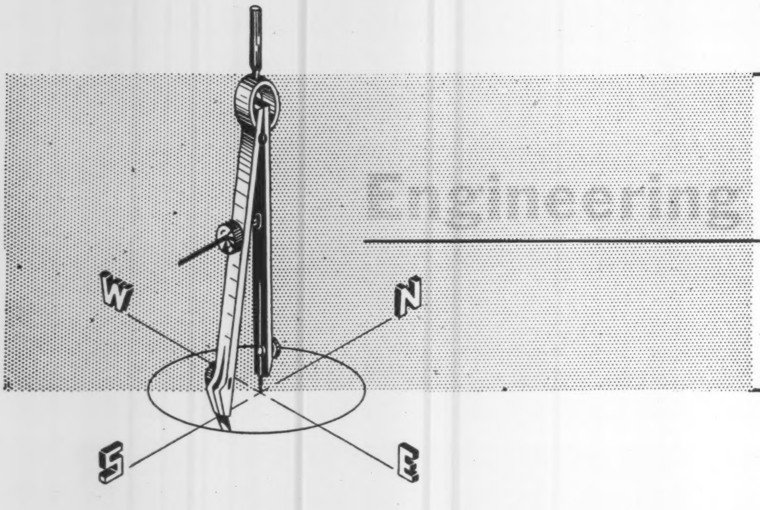
ANCHOR COUPLING CO. INC.
Dept. MD-122, Libertyville, Illinois
I want to know more about Anchor Ductile Sleeve Couplings and Hose. Send me catalog sheets.

Name ____________ Position ____________
Company ____________
Company Address ____________
City ____________ (____) State ____________



Engineering News Roundup

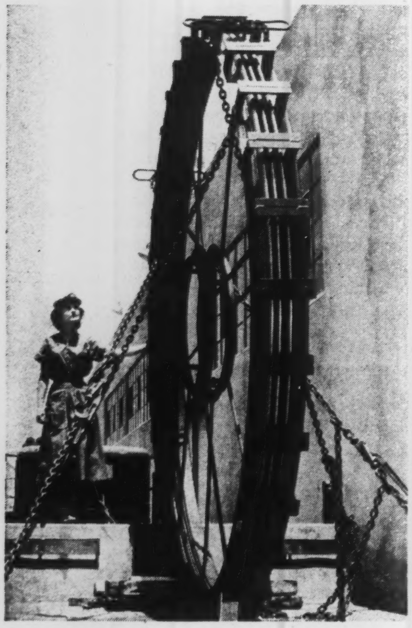
Huge Expansion Joints Built for Power Plants

Some of the largest expansion joints ever made for gas turbine power plants are being built by Solar Aircraft Co. Each of the joints, which are used to accommodate thermal expansion in waste heat boilers and regenerators, has three convolutions which form a leakproof joint but which are flexible to allow the connected sections to expand or contract with temperature changes.

The convolutions are made of 0.140-inch thick Type 321 stainless steel and are attached to standard carbon steel or low alloy steel weld ends.

Special welding equipment was designed for use in joining the assemblies, and a hydraulic hoist was built to position the bellows for welding and to support the welding equipment and operators.

Expansion joint to be used in GE stationary gas turbine power plant



New Type Helicopters Ordered for Services

Free from the complicated engine and transmission equipment found in most helicopters, a new model helicopter developed by Hiller Helicopters is controlled by two hand controls. The Hiller HJ-1 "Hornet" is powered by twin ram-jet engines which weigh only 12 pounds each, mounted on the tips of two 23-foot rotor blades. These engines, which compare in size to large watermelons, have no moving parts and may be disassembled from the blades in a few minutes with a screwdriver. They burn various types of low-cost fuel, including the low grades of gasoline, kerosene or diesel fuel oil, and each develops approximately 35 horsepower.

The two-place aircraft weighs approximately 350 pounds empty, has a useful load of 600 pounds and a maximum forward speed of 80 mph.

Five of these helicopters have been ordered, and two are to be delivered to the Army, two to the Navy and one to the Marine Corps for evaluation tests before next June. Development work was begun on the "Hornet" four years ago, and several models have been flown in test flights. Numerous "power-off" landings have been made from altitudes up to 3000 feet.

Transistors Used In Trial Installation

Transistors, tiny electronic amplifiers invented at Bell Telephone Laboratories, have replaced vacuum tubes in a trial installation in dial switching equipment in Englewood, N. J. This equipment enables Englewood customers to dial direct to telephones in distant cities.

Called the first serious rival of the vacuum tube, the transistor is much smaller and more rugged, and requires much less power.

Electrical signals generated in the new transistor units send the numbers of called telephones from one central office to another. This operation is now accomplished by vacuum tubes embodied in a large

Small enough to be held between two fingers, a transistor is pictured with an oscillator assembly

assembly serving a number of circuits within a single telephone central office. Signals thus generated must be distributed through special cable to the individual circuit. With the new transistor equipment, signalling equipment can be placed exactly where it is needed instead of being centrally located. Unlike vacuum-tube units to which heating power must be supplied continuously, transistors operate only when needed and use very little power. One unit can be operated on less than half the power required by an electric clock. On a single telephone call, the unit will be used less than two seconds.

ASEE Lists Highest Engineering Enrollments

The American Society for Engineering Education recently compiled a list of the ten universities and colleges in this country which have the largest enrollments of undergraduate engineering students. The table lists these schools in the order of their respective day-student enrollments:

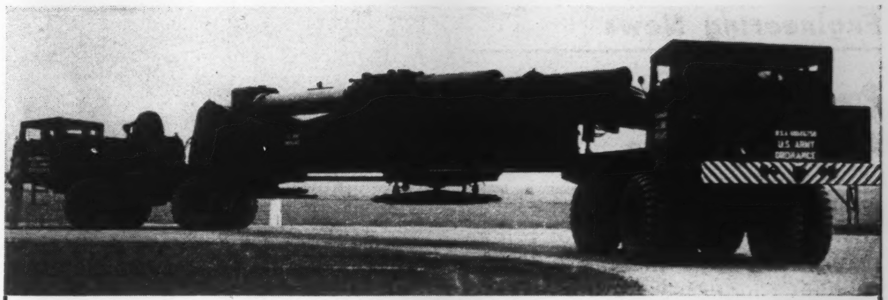
College	No. of Students Day	Totals*
Purdue University	3721	3734
University of Illinois	3102	3102
Georgia School of Technology	2804	2804
Rensselaer Polytechnic Institute	2585	2802
Pennsylvania State	2530	2549
Massachusetts Institute of Technology	2359	2359
College of the City of New York	2151	3026
Illinois Institute of Technology	1376	5141
New York University	1176	2432
Polytechnic Institute of Brooklyn	1156	3380

---

* Including evening and special students.

Cold-Forged Chromium

Malleable enough to forge at extremely low temperatures, a highly refined chromium metal has been produced by metallurgists of the Bureau of Mines. The new metal is produced by refining electrolytic chromium in a hydrogen atmosphere at high temperature and could be forged even at liquid-air temperatures. In sheet form it could be spot welded to chromium or iron and rolled, drilled, sawed, ground and filed.



Army Gun Fires Atomic Projectiles

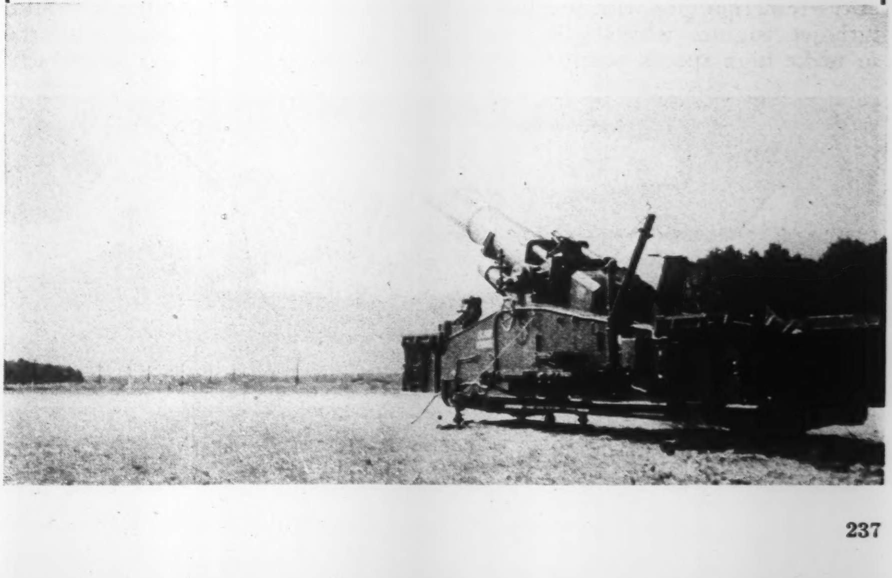
A new weapon which can fire both atomic and conventional projectiles, the 280-mm T131 gun is the Army's largest caliber artillery piece having complete mobility. Unveiled recently by the Department of Defense at its Aberdeen, Md., proving ground, the new gun can be readied for action faster than any other equipment of its kind now in use.

Unlike air-delivered atomic bombs, atomic shells can be fired from the new gun in any kind of weather, day or night. The T131 can fire with accuracy comparable to conventional artillery in the shorter ranges and is considered to be four times more accurate at long ranges than any mobile artillery pieces developed prior to World War II.

Range of the weapon is 20 miles, elevation is 0 to 55 degrees; traverse is 360 degrees.

Although it weighs approximately 85 tons, the T131 is not much larger than the heaviest field artillery piece now in service. It can cross bridges capable of carrying any standard piece of equipment in an Army division, can travel cross-country as well as on highways, and will fit into an amphibious landing ship. It is carried suspended between two engine cabs which can travel either forward or backward or turn at right angles and travel parallel to each other.

Balanced vertically by a hydropneumatic equilibrator system, the gun can be elevated or depressed by exerting only 30 pounds of pressure on a handwheel in the event that the power unit fails. The entire carriage is balanced on a turntable equipped with a steel ball that fits a socket in the carriage, plus three jacks with wheels which ride a track around the circumference of the turntable. When jacked up in the rear, the carriage can be rotated horizontally through a complete circle. Jacks also level the gun on uneven terrain.

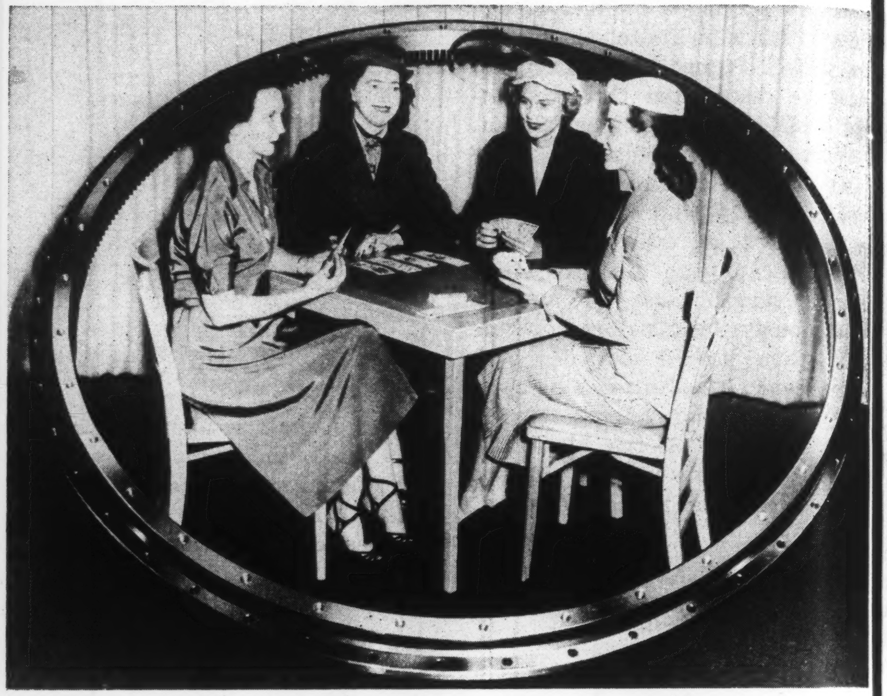


Engineering News

Precision Ball Bearings Made in Giant Size

Precision ball bearings large enough to encircle a table of bridge players are being manufactured by Kaydon Engineering Corp. for the 90-mm gun mounts of the new Patton M-48 tank. The bearings measure 85 inches ID and 93¾ inches OD.

The deep flame hardening process employed in the manufacture of the bearings permits integral gears to be cut on the raceways and drilled and tapped holes to be spaced accurately, because such work is done after hardening. Distortion due to heat treating is thus eliminated.



To illustrate the size of ball bearings being manufactured for gun mounts of the new Patton M-48 tank, this photograph was made of a bridge game being played within the circumference of a bearing

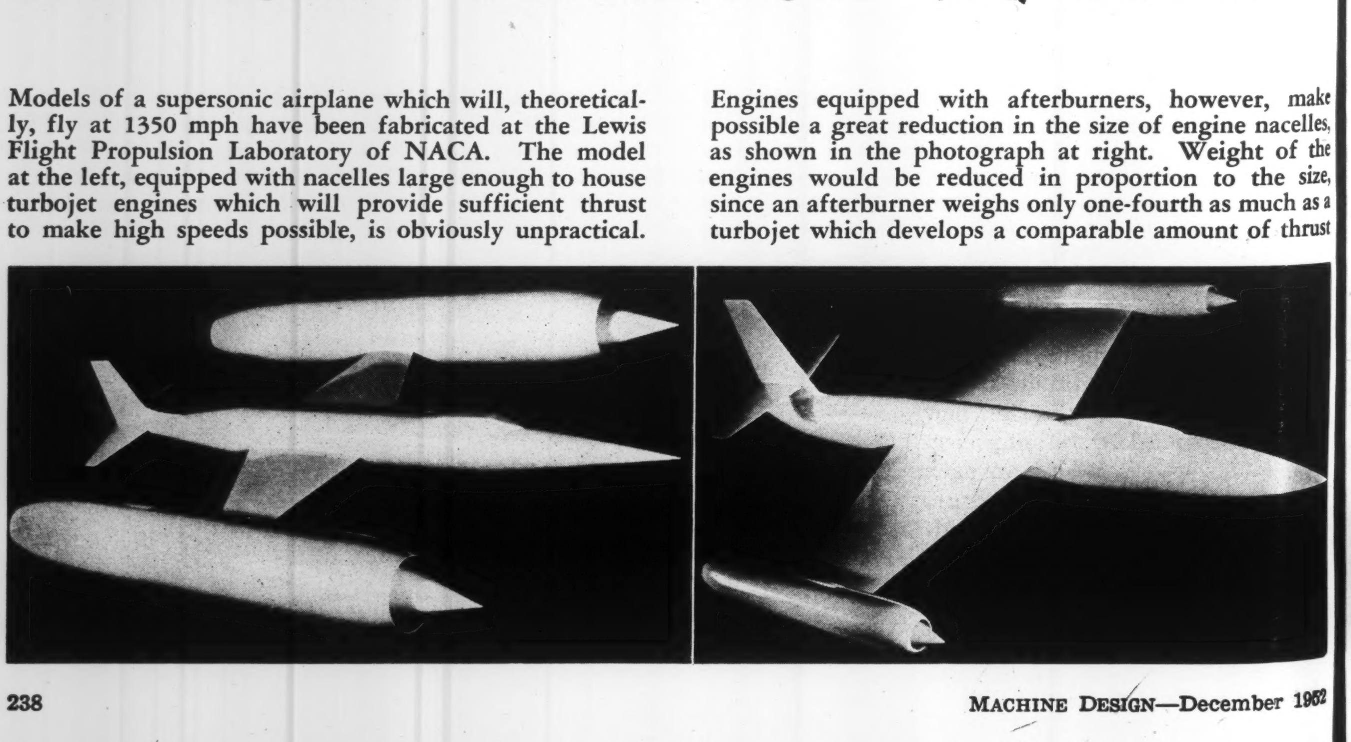
Predict Future Of Measuring Devices

At the Meter and Instrument Specialists Conference held by General Electric, several members of the company's meter and instrument department made predictions relating to the use of electrical measuring devices.

Acting manager of marketing John C. Garrett stated that each new technical development in the world today brings about a corresponding increase in the demand for electric measuring devices. He expects that, as new developments increase, the demand for such devices will almost double within the next decade.

In the same vein, C. Howard Black, general manager of the department, said that U. S. industry can increase its profits by extending the use of specialized measuring instruments and thereby cutting production costs. He cited a case where the use of a gauss meter, an instrument which gives direct readings of magnetic field strengths, cut inspection costs for one manufacturer by one-third and at the same time resulted in a 20 per cent saving on material.

I. F. Kinnard, department manager of engineering, in hailing creative engineering as "the foundation of America's vast industrial might," predicted that nuclear physics would play an important role in the development of future precision measurement devices.



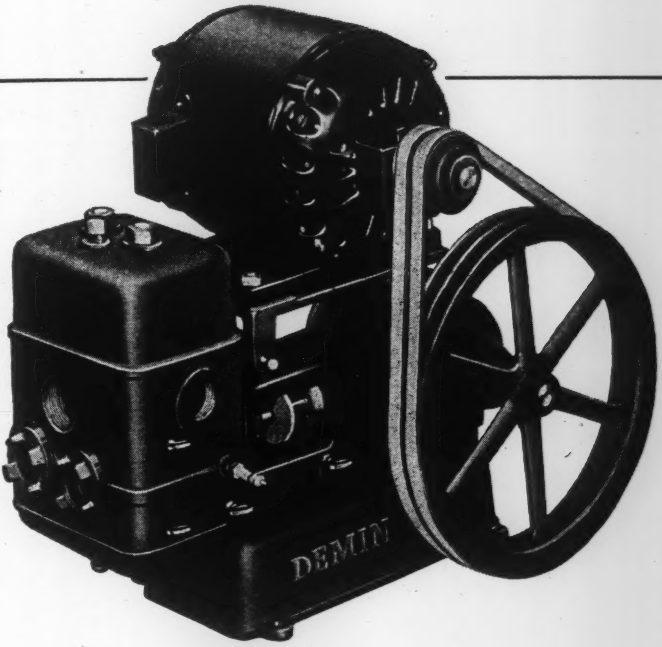
Models of a supersonic airplane which will, theoretically, fly at 1350 mph have been fabricated at the Lewis Flight Propulsion Laboratory of NACA. The model at the left, equipped with nacelles large enough to house turbojet engines which will provide sufficient thrust to make high speeds possible, is obviously unpractical. Engines equipped with afterburners, however, make possible a great reduction in the size of engine nacelles, as shown in the photograph at right. Weight of the engines would be reduced in proportion to the size, since an afterburner weighs only one-fourth as much as a turbojet which develops a comparable amount of thrust

teamed for top performance!

Deming Water Pumps

and

Gilmer V-Belts



Deming Duplex Pumping Unit, like other Deming reciprocating pumps, is originally equipped with GILMER V-Belts for long, trouble-free service.

Private water systems—such as those manufactured for more than 70 years by The Deming Company, Salem, Ohio—supply running water to millions of suburban homes and farms. Users demand that their operation be quiet, dependable, require little or no attention. That's why Deming has, for years, equipped its belt-driven water pumps with GILMER V-Belts!

And Deming is only one of many such leading machinery manufacturers who entrust the reputation of their products to GILMER V-Belt drives. Certainly, here is evidence of the most convincing sort that designers, engineers, men who know drive requirements best, recognize the fundamental soundness of GILMER V-Belt design . . . the uniform quality of GILMER V-Belt construction.

The makers of Gilmer belts have always been happy to work with designers of machinery, providing special belt sizes or constructions when necessary . . . have built up a tremendous assortment of belt molds, both standard and special. Write for the Gilmer V-Belt Guide and latest Mold List. Use them when designing your drives . . . and trust GILMER V-Belts to match your machine's own top performance.

NEW YORK BELTING & PACKING CO. • Founded 1846

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O-M CYLINDERS
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Available in a full range of sizes (1½" to 8" bores), powerful, dependable O-M Cylinders require ⅓ *less installation space* than conventional type cylinders of equal bore. Tie rods and bulky end caps have been eliminated by a special *Internal Locking* process found only on O-M Cylinders. Saves space . . . provides better balance . . . permits use of more bore power for the job. O-M Cylinders are easy to install, easy to repack. All machined steel with bearing bronze (no castings). Complete range of mounting brackets, interchangeable bore for bore.

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Engineering News

Develop Resin for Embedding Electronic Assemblies

Containing a small quantity of acrylonitrile monomer, a new casting resin for embedding or "potting" electronic components and assemblies has recently been developed by the Ordnance Development Division of the National Bureau of Standards. Easily and economically manufactured from available raw materials, the new AN-5 resin has good storage properties even without refrigeration. Its physical properties and electrical characteristics at both high and low frequencies are claimed to be generally as good as those of more expensive and hard-to-store resins.

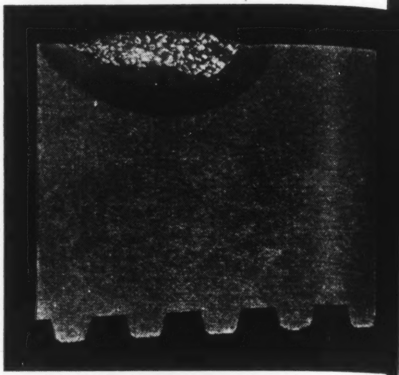
Automatic Hardfacing Process Announced

Hardfacing with tungsten carbide is possible with a new automatic feeding unit developed by Air Reduction Co. Tests have shown that the deposition of tungsten carbide hardfacing material by this method is limited only by the ability to position the work and the arc in proper relationship to each other.

The manner of deposition of loose, granular, pure tungsten carbide particles minimizes reduction of particle size by solution of the tungsten carbide into the base metal. It also minimizes the heat-affected area adjacent to the deposit.

In operation the inert gas shielded arc melts the base metal, producing an elongated pool, and th tungsten carbide particles ar poured into this pool behind th arc. The rate of tungsten carbid feed from the hopper mounted o the Heliweld head is electricall controlled. Abrasion resistance o deposits made by this process i reported to be greater than tha attainable with other arc methods

Feeding tungsten carbide particles into the pool behind the automatic gas-shielded arc



Section of a deposit on a tool join showing distribution of correct pa ticle size and narrow heat-affecte zone of deposition

Passenger Subway Proposed For Downtown Cleveland

Construction of a 3300-foot bel conveyor passenger subway under neath Euclid Ave. and east fron the Public Square in downtow Cleveland has been proposed. Cos of the conveyor system, designe by Goodyear Tire and Rubber Co is estimated at a little more tha half that of a transit loop.

The subway would use the sam type of conveyor belt equipmen designed for the Grand Central Times Square subway shuttle i New York City (MACHINE DESIGN October 1952, Page 245.) Two in termediate stops would be mad between Public Square and th eastern terminus. The design call for the use of small passenger car riding on high-speed main conveyo belts with slow-speed belts at load ing and unloading points.

Within the next two years a rap id transit line now under construc tion will be transporting an esti mated 32,000,000 people annuall to and from the Public Square, an it was pointed out that the convey or subway would distribute a larg segment of these commuters t downtown stores and offices.

how NORGREN lubricates an air cylinder with less than 1 cfm of air

Cylinder counterbalances "side head" of car wheel borer made by *Niles Tool Works* of the *Baldwin-Lima-Hamilton Corp.*

PROBLEM

To obtain dependable oil fog lubrication of air cylinder through ¾" pipe with less than 1 cfm air flow (insufficient to operate any ¾" lubricator).

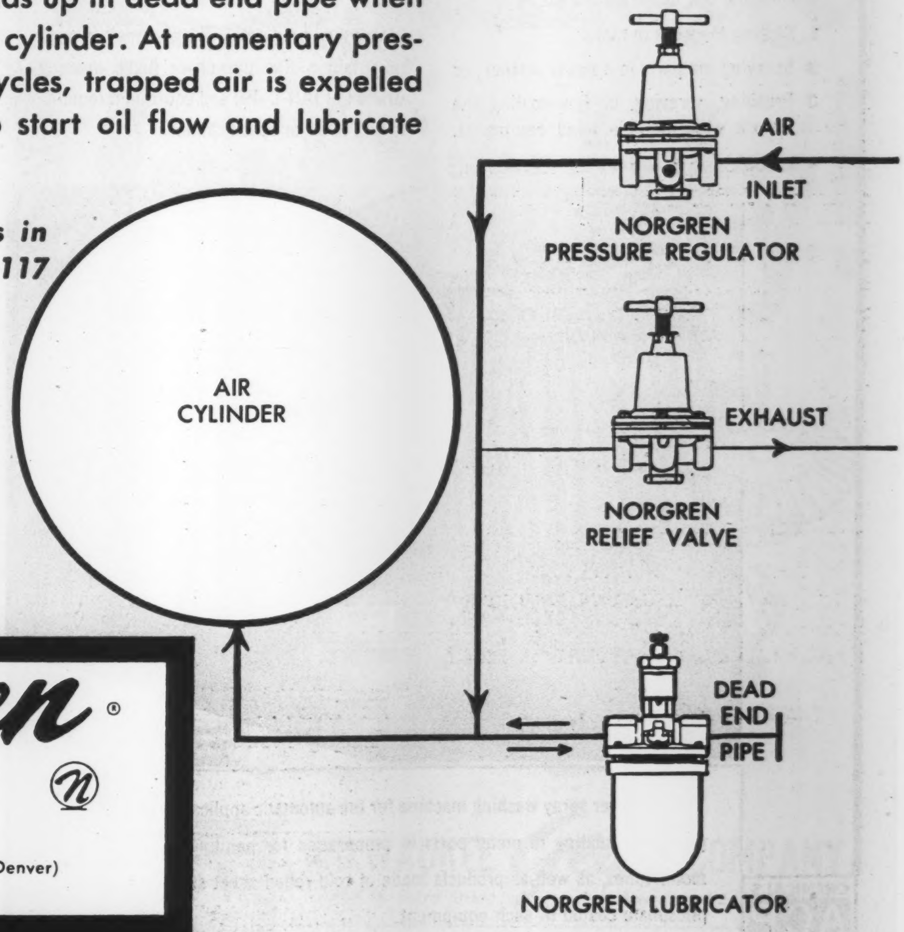
SOLUTION

Use of Norgren Oil Fog Lubricator on a dead end pipe.

RESULT

Air volume builds up in dead end pipe when air flows to and from cylinder. At momentary pressure drop between cycles, trapped air is expelled with sufficient cfm to start oil flow and lubricate cylinder.

Write for the details in Norgren Blueprint No. 117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Technical Service Data Sheet
Subject: GRANODIZING* FOR LONG PAINT LIFE ON STEEL

"GRANODINE" FORMS A DURABLE PAINT BOND

Granodizing forms a crystalline, zinc phosphate coating on steel. This ACP paint-bonding process chemically changes the surface of steel into an inert non-metallic coating made up of thousands of microscopic zinc phosphate crystals.

Granodized steel thus presents a surface much more receptive to paint than untreated steel. Its crystalline structure permits a firm and durable "keying" or bonding of the paint finish. And the "Granodine" zinc phosphate coating itself is actually integral with the metal from which it is formed.

"GRANODINE" CAN BE APPLIED BY DIPPING, SPRAYING OR BRUSHING

Granodizing can be accomplished by:

1 Dipping the work in tanks;
2 Spraying the parts in a power washer; or
3 Brushing, spraying, or flow-coating the work with portable hand equipment.

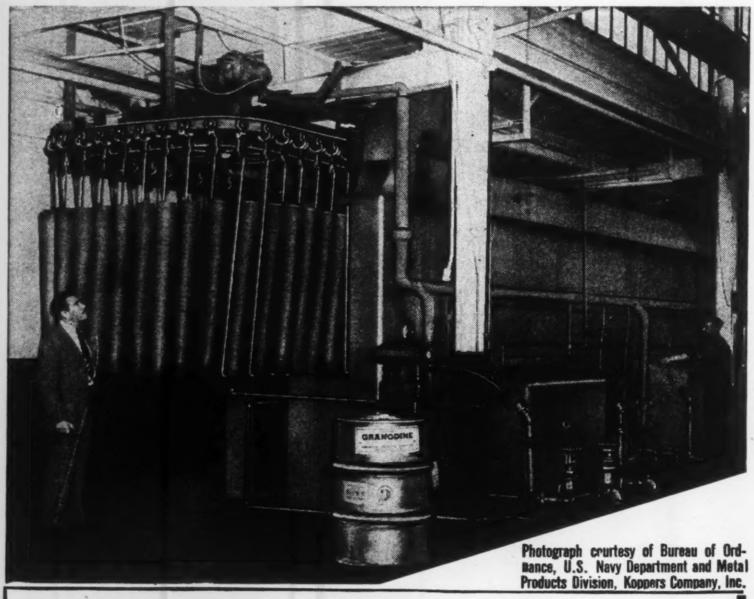
Choice of process is usually decided by such factors as the size, nature, and volume of production.

"GRANODINE" STANDARD PRACTICE ON BOTH CIVILIAN AND MILITARY PRODUCTS

Automobile bodies and sheet metal parts, refrigerators, washing machines, cabinets, etc.; projectiles, rockets, bombs, tanks, trucks, jeeps, containers for small arms, cartridge tanks, 5-gallon gasoline containers, vehicular sheet metal, steel drums and, in general, products constructed of cold-rolled steel in large and continuous production are typical of the many products whose paint finish is protected by "Granodine".

In military production, "Granodine" is used to obtain a zinc phosphate finish meeting Grade I of JAN-C-490 and equivalent requirements of other specifications.

*"GRANODINE" Trade Mark Reg. U.S. Pat. Off.



Photograph courtesy of Bureau of Ordnance, U.S. Navy Department and Metal Products Division, Koppers Company, Inc.

Typical power spray washing machine for the automatic application of a protective phosphate coating to metal parts in preparation for painting. These 5" rocket motor tubes, as well as products made of cold rolled sheet steel, are effectively phosphate coated in such equipment.

CHEMICALS ACP PROCESSES

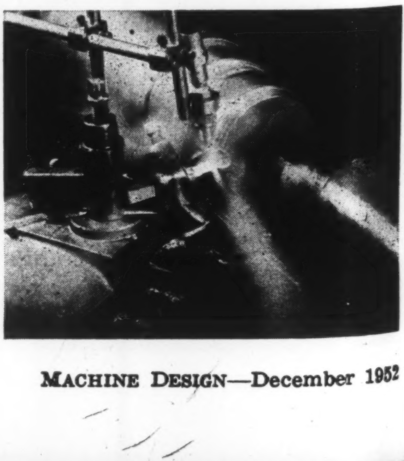
Carbon Dioxide Used As Machine Tool Coolant

Although liquid carbon dioxide has been used as a tool coolant for many years, the greatly increased use of special alloys is widely expanding use of this procedure, according to Pure Carbonic Co. In production operations as well as experimentally, liquid carbon dioxide is being employed as a coolant for turning, milling, boring, drilling, tapping and broaching, especially on such materials as titanium which react with air at cutting temperatures. It has also found use in the grinding or preparation of tools employed in these operations.

Cooling is effected by releasing the gas at high pressure (850 psi at 70 F) to atmospheric pressure through a suitable nozzle. Various nozzles produce desired spray patterns such as cone, fan or pinpoint. The gas changes to snow similar to dry ice upon contact with the metal. This snow evaporates leaving no residue.

Longer tool life, little or no work hardening, finer finish, less buildup on the tool and higher speeds are all claimed as advantages of using liquid carbon dioxide. Others are the accurate control of temperature, thus insuring dimensional and metallurgical stability, and lack of reaction between the gas and reactive materials.

Carbon dioxide being used as a coolant to remove heat caused by separation of the chip from the stock. Quick removal of heat by this method is claimed to lengthen tool life and permit more accurate machining by preventing the material from warping as a result of heat



Engineering News

Powerful Radiation Source Installed

Consisting of approximately 2.5 pounds of a radioactive form of cobalt known as cobalt 60, a radiation source equal in intensity to twice the world's supply of radium was recently installed at the Knolls Atomic Power Laboratory in Schenectady, N. Y. This laboratory is operated by General Electric for the Atomic Energy Commission.

Radiation from the source is so intense that it causes a bluish-white glow in the nine-foot depth of protective water covering the cobalt 60. In darkness, the tank and the surrounding area are illuminated by this glow.

The laboratory will use the new installation in connection with work on the design and construction of a full scale, land-based model of an atomic power plant for U. S. Navy submarines. Physical properties of many materials to be used in constructing this power plant may be altered by the powerful rays generated in the atomic reactor. By lowering samples of the materials into the water which covers the cobalt 60 such effects may be tested on a small scale.

The radioactive cobalt is contained in ten cylindrical capsules which are mounted in holes in a steel plate. The capsules are kept at the bottom of a concrete pit and, with the aid of submerged lights, may be seen through the water. By means of remote control devices, the capsules may be moved around and test samples placed in position near them.

◆

Hans G. Belitz was recently promoted to the position of sales manager for **G. H. Leland Inc.,** Dayton, O.

◆

Because the company has done much experimental research with titanium, the U. S. Air Force has awarded a contract for research and development to **Ryan Aeronautical Co.,** San Diego, Calif. Work for the Air Force is to determine the best methods of processing titanium for use in conjunction with exhaust systems.

Versatility!

Since 1918, gear buyers have known that they could turn to Milwaukee Gear for intelligent handling of their most difficult gear problems. But Milwaukee Gear is a 1953 plant—not a 1918 one. In its completely new plant are the skills and the machines to turn out the gears you'll be using in 1963. Send us prints and let our engineers help you solve your gear problems.

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Gears of Every Description Since 1918

PIT FOR DRAIN PIPES
PIT FOR FEED AND DRAIN PIPES
SECTION-II-II

Rod finishing mill, made by Birdsboro Steel Foundry and Machine Company. Clipper Seals are used to seal pinion shaft and line shaft extension. Clipper Seal's flexible lip, held in light but positive contact with the shaft by a specially designed garter spring, assures effective sealing even at high speeds.

Need an oil seal for high shaft speeds?

Birdsboro chose Clipper Seals

The Birdsboro 8-stand finishing train shown above is expected to operate around the clock, day in and day out. And since it is to be part of a large, high-speed, steel rod producing unit, Birdsboro designed it to be as maintenance-free as possible.

In order to minimize down time, particular attention was paid to bearing design and lubrication. The mill stands are equipped with open, water-lubricated bearings. Because of high shaft speeds, bearings in the combination spiral bevel gear reduction and pinion stand are anti-friction in type, lubricated with circulating oil, and sealed with Clipper Seals.

Birdsboro engineers chose Clipper Seals for this application because of their outstanding ability to withstand the heat of friction generated by high shaft speeds . . . and their ability to make a tight and lasting seal against the circulating bearing lubricant.

Still other reasons for Birdsboro's preference for Clipper Seals: They are precision-molded, compact in design, and exceptionally easy to install. They may be removed and replaced without impairing their sealing efficiency. And because of their unique design, Clipper Seals cause a minimum of shaft wear.

Precision-molded Clipper Seals are made in a variety of designs to meet almost any sealing condition. They are available in split and endless types, with a choice of heel and lip combinations for various services. For details, write for Brochure PK-46A. Address, Johns-Manville, Box 60, New York 16, N. Y. In Canada, 199 Bay Street, Toronto 1, Ontario.

JOHNS-MANVILLE JM PRODUCTS

Johns-Manville CLIPPER SEALS

To Build Steam Catapults For Aircraft Carriers

Regarded by naval engineers of both the United States and Great Britain as one of the most important developments for naval aviation since World War II, British-developed steam catapults will be built by McKiernan-Terry Corp. and E. W. Bliss Co. for use on U. S. Navy aircraft carriers.

Tests have proved that the steam powered mechanism can hurl the Navy's jet fighters into the air even when the carrier is headed downwind or alongside a dock.

The 60,000-ton *U. S. S. Forrestal,* now under construction, is to have four catapults, two of which will be American manufactured, using some British parts. It is expected that delivery of catapult parts from Britain will begin next May, and first installations in the carrier *Hancock* are planned for early 1954.

◆

The annual Doehler Award for "the outstanding achievement contributing to the advancement of the die casting industry" was presented to David Laine, secretary of the American Die Casting Institute Inc., for his activities in behalf of the industry during the past year.

All parts of this industrial ventilating fan—even the blades—are made of Lucoflex, an unplasticized, hard polyvinyl chloride material. Since the plastic material produced by American Lucoflex Inc. resists all types of chemical fumes, life of the fan in electroplating and chemical plants is longer than that of metal units. Operation is claimed to be as efficient as a metal fan

LEDEX ROTARY SOLENOIDS

... double efficiency and **LOWER COST 70%**

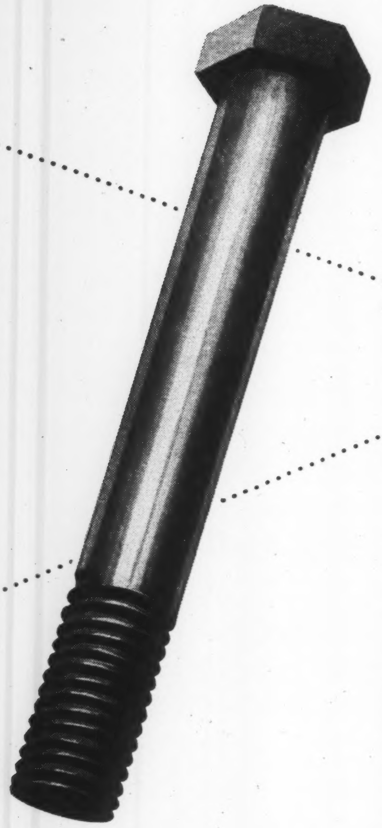
for The Cincinnati Time Recorder Company

The compact, powerful number five Ledex Rotary Solenoid is used to replace the bulky old type solenoid in the Cincinnati series 800, Automatic Time Recorder. By comparison Ledex Rotary Solenoids have 1/7 the weight . . . produce twice the power output with the same electrical input . . . proved to be more dependable and easier to install . . . *and reduced the cost of this component 70%*. The actual size illustration of the solenoids show the advantage of Ledex compactness . . . 1/6 the volume.

Let Ledex Engineers assist you in choosing rotary solenoids that will save production costs and help increase the efficiency of your products. Six basic models range in diameters from 1⅛″ to 3⅜″, with torque values from ¼ to 50 pound-inches. Various power linkages and types of mountings are available. Write today for descriptive literature.

G. H. Leland INC.

123 WEBSTER STREET, DAYTON 2, OHIO



You wouldn't

hold a bolt

to ± 0.0002 in.

Why pay for unneeded precision in ball bearings?

In many applications where speeds and loads are moderate, you don't need a precision bearing. When this is the case, Schatz "Commercial" Ball Bearings can cut your costs by as much as 85%—*without any sacrifice in operating efficiency.*

Why are savings like this possible? Because "Commercial" Ball Bearings are designed to wider tolerances than precision bearings...because they are available unground, partially-ground, or fully-ground. And, because, in almost all cases, cages are not used.

If you have an application where speeds and loads are moderate, it will pay you to look into Schatz "Commercial" Ball Bearings. To learn how you may save, write for literature described below.

THE SCHATZ MANUFACTURING COMPANY
6760 Fairview Avenue, Poughkeepsie, New York

Schatz "Commercial" Bearings used on these products

Dishwashers • Outboard motors
Automobile steering mechanisms
Elevators • Box machinery
Office equipment
Flexible shafts • Lawn mowers
Masonry cutting equipment
Textile machinery • Farm equipment
Laundry equipment

What about your product?

The oldest, largest manufacturer of "Commercial" ball bearings

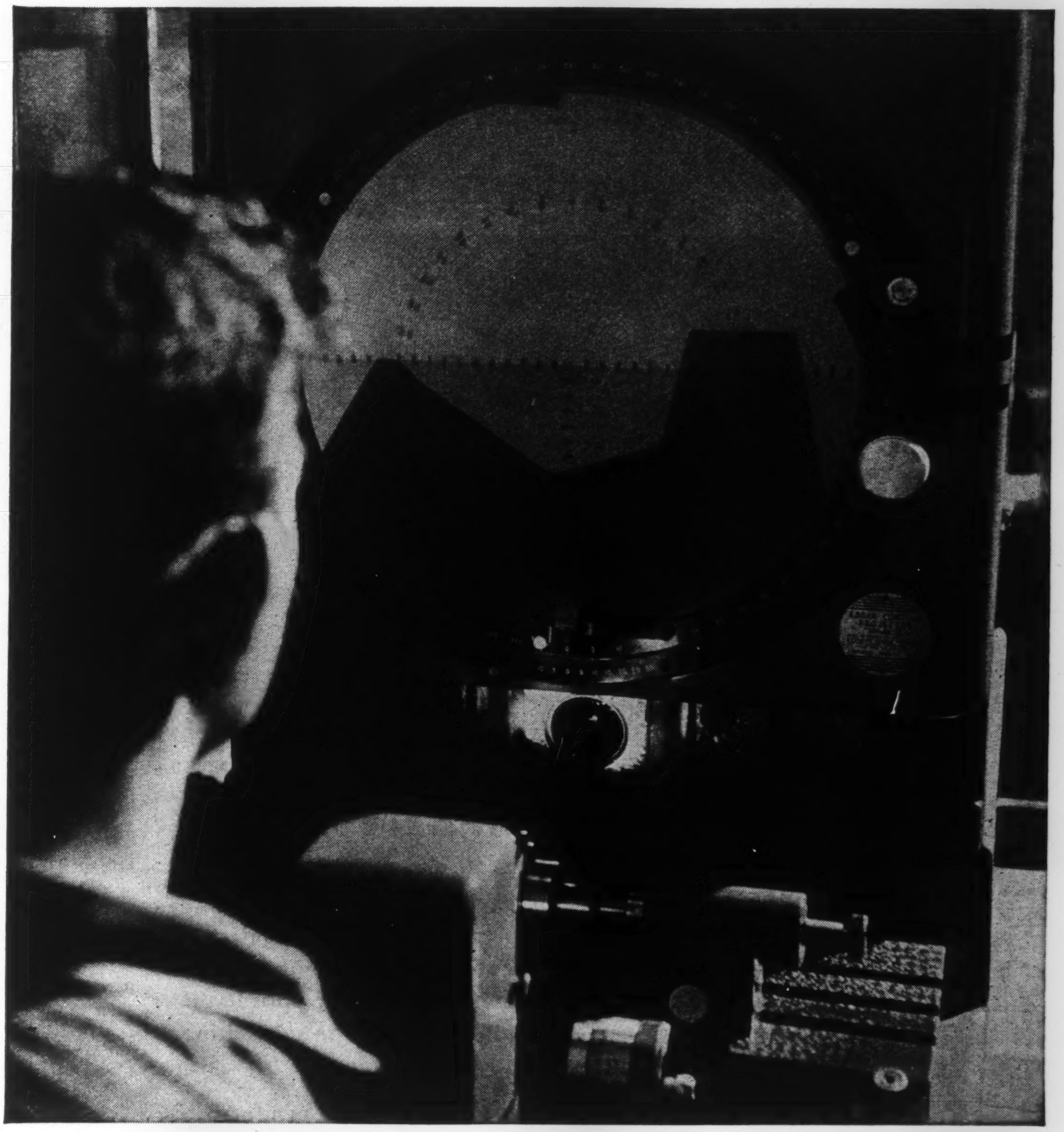
SCHATZ
"Commercial"
BALL BEARINGS

Technical literature available:

Schatz Catalog 11 contains drawings and specifications of Schatz Ball Bearings.

Technical Bulletin tells how to determine proper type and size "Commercial" Ball Bearing for various speeds and loads.

Nylon Bearing Parts discusses advantages of nylon parts in "Commercial" bearings.



Front Row at the Raceway

TAKING STEPS to assure that the sides of bearing rings will be parallel to each other, and to the ball track, begins with proper tooling.

That's why Federal spares no pains to gage the form tools used to produce its ball bearings. Here, for example, a technician inspects contours in an optical comparator; a prism of light projects the tool outline, 20 times enlarged, onto the gridded screen. By careful inspection, he can often hold difficult tolerances to 0.0001 in. or finer.

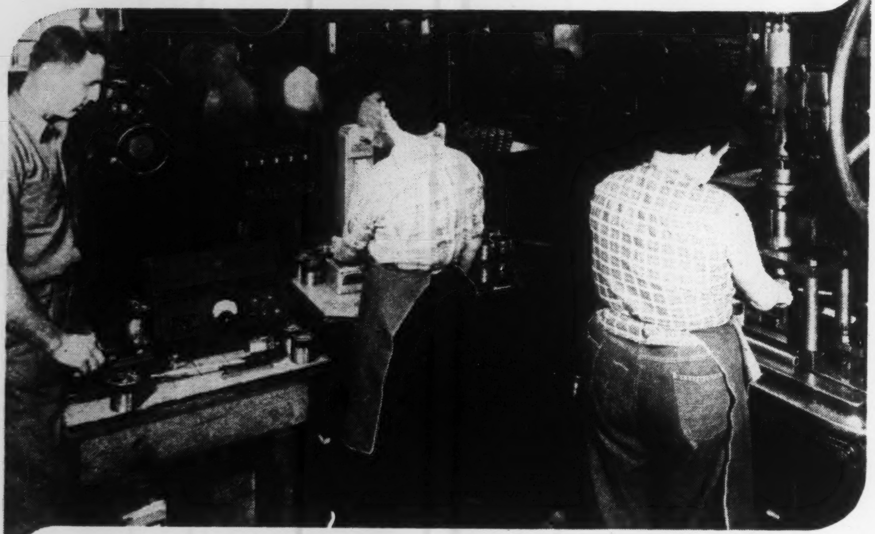
It's by this thinking in terms of perfection, not time, that Federal produces quiet, friction-free ball bearings. Such precautions are your assurance of top performance from *every* Federal Ball Bearing.
The Federal Bearings Co., Inc., Poughkeepsie, N. Y.

Federal
Ball Bearings

One of America's Leading
Ball Bearing Manufacturers

MEASURE IN MICROINCHES RMS

"An Essential Unit of Our Production Line"



says BRADFORD PRODUCTION MACHINE COMPANY about the PROFILOMETER

"In our production of cylinders for hydraulic steering units, we consider the Profilometer an essential piece of equipment . . . and the spot for it is right on our production line," says Bradford Production Machine Company of Detroit.

The above illustration shows the three final operations of the production line. The I.D. of the cylinder is bearingized, gaged for dimensional tolerances, and then surface roughness is checked with the Profilometer. Only seconds away from the machining operations, the Profilometer provides the information necessary to assure constant control of the specified surface finish—which, in this case, is from four to six microinches.

In plants throughout the world—wherever control of surface roughness is a requirement—you will find the Profilometer in use as a fast, simple and accurate shop tool. On the job at the time when surfaces are being produced, it can and does make possible many worthwhile savings in production costs.

PROFILOMETER

To learn how the Profilometer can be used to advantage in your plant, write for these free bulletins.

Profilometer is a registered trade name.

MICROMETRICAL
MANUFACTURING COMPANY
formerly PHYSICISTS RESEARCH COMPANY
Instrument Manufacturers
ANN ARBOR 13 MICHIGAN

Establish Foundation for Education and Research

Because of the shortage of engineering students in the United States and the importance of metals research, the 22,000 members of the American Society for Metals have voted unanimously to establish a Foundation for Education and Research.

An initial $650,000 has been appropriated for the Foundation. Annual income from assets will amount to approximately $30,000, which will be used for the advancement and dissemination of scientific knowledge, particularly with respect to the technology of metals, for the use and benefit of the public at large. This program will be conducted either through education and research carried on by the Foundation itself or through the support of educational and research activities in established organizations and institutions.

◆

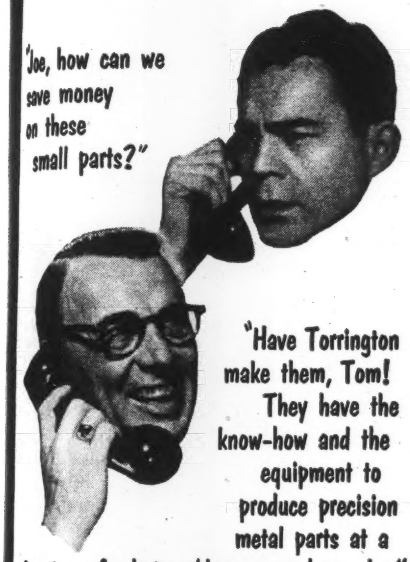
Meehanite Metal Corp., New Rochelle, N. Y., has concluded an agreement with **Crofts Engineers Ltd.** for the exclusive right in the United States, Canada, Mexico, Central, South American and other countries, to enter into agreements with industries for use of a new process and installation of necessary equipment for melting metal borings. The new process results in improved economy of cupola operation. Turnings, borings, etc., are fed into a chute placed at cupola platform level and are forcibly introduced through the refractory wall of the cupola just above the melting zone. Operating with negligible metal loss, the process eliminates the cost of a briquetting process.

◆

As a result of the shortening of the name of the parent company, the new name of Wolverine Tube Div. will be **Wolverine Tube Div. of Calumet & Hecla Inc.**

◆

Associated with **American Blower Co.,** Detroit, since 1923, E. W. Petersen was recently appointed general sales manager for the company.



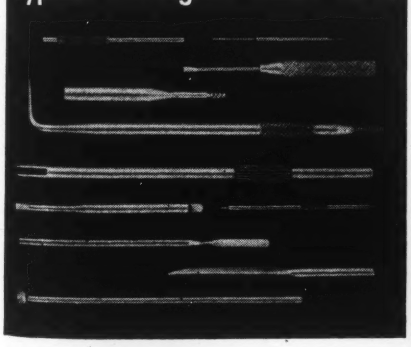
"Joe, how can we save money on these small parts?"

"Have Torrington make them, Tom! They have the know-how and the equipment to produce precision metal parts at a fraction of what we'd pay anywhere else."

When it comes to holding the line on costs—and holding strict tolerances at the same time—it takes experience and facilities. For over 86 years, Torrington has been making precision metal parts. Production facilities include batteries of automatic and semi-automatic machines—many of them Torrington-designed—and one of the finest heat-treating departments in the world. In addition, we have at our disposal the combined experience and facilities of all 11 plants of The Torrington Company.

If you need precision metal parts, ask us for a quotation. Just send us a sample or blueprint and tell us how many you need.

Typical Torrington-Made Parts



THE TORRINGTON COMPANY
Specialty Department
553 Field Street • Torrington, Conn.

Makers of
TORRINGTON NEEDLE BEARINGS

Engineering News

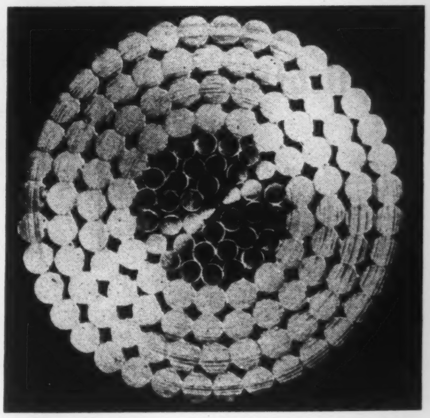
Measures Low Porosity In Metal Castings

Believed capable of accurately measuring leakage rates as low as 10^{-8} cubic feet per square inch per hour at one atmosphere of pressure, an improved method for measuring the porosity of metal castings has been developed at Sam Tour & Co. Inc.

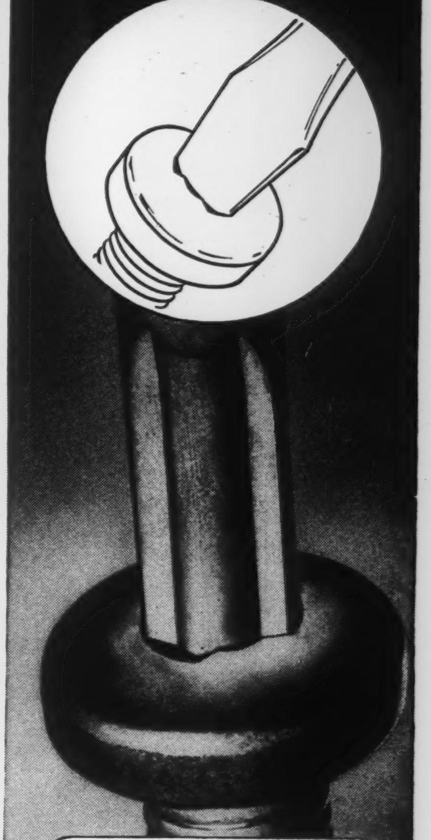
The method was devised to measure the effectiveness of a plastic impregnant in reducing the porosity of aluminum castings to be used in high vacuum installations. Previous vacuum techniques of measurement gave unreliable results at low porosity levels.

The new technique is based on trapping and weighing the amount of carbon dioxide which passes through a test plate. Pure, dry carbon dioxide is introduced into one side of a chamber which is divided by the test plate. Pressure of the carbon dioxide is accurately maintained at 15 psi throughout the test. A stream of oxygen, free of carbon dioxide, sweeps through the chamber on the other side of the test plate at approximately at-

Over 2½ inches in diameter, the world's largest stranded electrical cable ever fabricated for an overhead transmission line is shown in cross section. The cable consists of 108 aluminum wires over a core of steel wires. It will be used by the Aluminum Co. of Canada for a new aluminum development in British Columbia and will carry power over a mountainous, ten-mile pass section of a fifty-mile long power transmission line. The cable has an ultimate strength of 135,700 pounds



UNITED CLUTCH HEAD® SCREWS



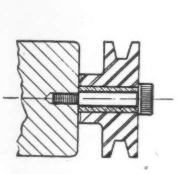
One of the many advantages afforded by Clutch Head screws is the ability to use a common screw driver of proper width to firmly seat or remove the screw. No other recessed head screw can offer you this advantage. Write for engineering booklet.

TYPE "A" BIT
NOT THIS

®Reg. U.S. Pat. Off.

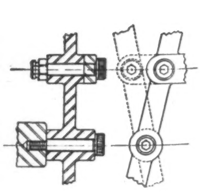
UNITED SCREW and BOLT CORP.
CHICAGO 8, ILL. • CLEVELAND 2, OHIO
NEW YORK 7, N. Y.

UNBRAKO® Shoulder Screw Applications



1. Stationary Shaft or Pivot

- A. Idler pulley
- B. Idler gear
- C. Circular form tool
- D. Lever, crank or linkage arm
- E. Cam
- F. Latch



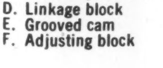
2. Moving Shaft or Pivot

- A. Linkage bar connection
- B. Cam
- C. Cam follower
- D. Ratchet
- E. Planetary gear or pinion

UNBRAKO SHOULDER SCREWS...
uniform, standardized, precision threaded industrial fasteners...HAVE NUMEROUS APPLICATIONS

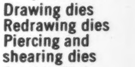
You can use these UNBRAKO Socket Head Shoulder Screws as stationary shafts or pivots, moving shafts or pivots, stationary guides, and for stripper plate and pressure pad applications. These UNBRAKO screws have shoulders held to close tolerances, finished threads close to the shoulder, and threads and heads concentric with the body. Write for descriptive literature. STANDARD PRESSED STEEL Co., Jenkintown 18, Pennsylvania.

UNBRAKO SOCKET SCREW DIVISION



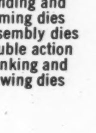
3. Stationary Guide

A. Locating pin in jigs and fixtures
B. Latch stop
C. Alignment of stationary members
D. Linkage block
E. Grooved cam
F. Adjusting block



4. Stripper Plate Uses

A. Blanking dies
B. Compound dies
C. Progressive compound dies
D. Drawing dies
E. Redrawing dies
F. Piercing and shearing dies
G. Combination blanking, drawing and piercing dies
H. Double action blanking and drawing dies



5. Pressure Pad Uses

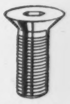
A. Cutting-off dies
B. Bending dies
C. Bending and forming dies
D. Assembly dies
E. Double action blanking and drawing dies

SPS

JENKINTOWN PENNSYLVANIA

Knurled Head Cap Screw

Self-Locking Set Screw



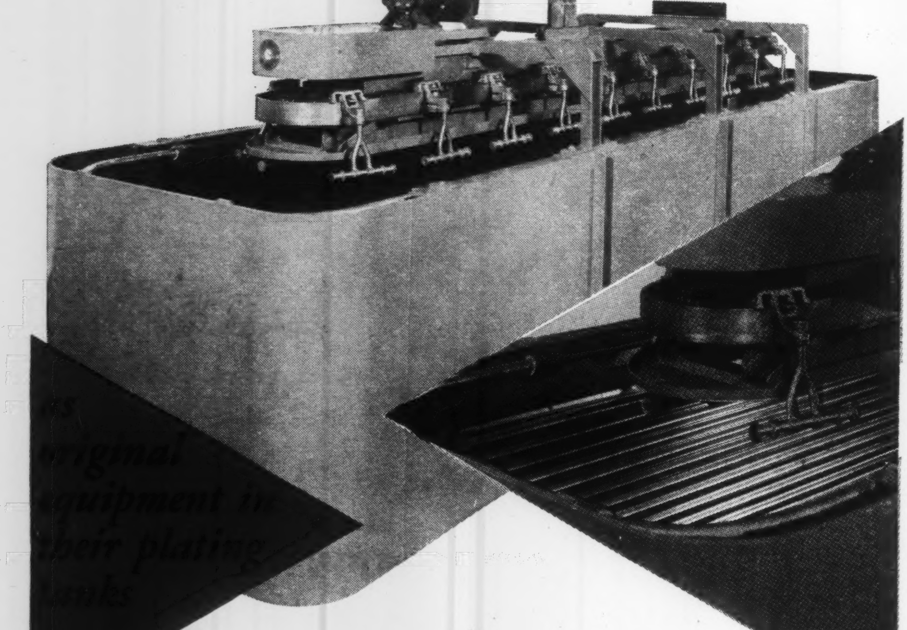
Flat Head Cap Screw

Shoulder Screw

Dowel Pin

of course...

CROWN RHEOSTAT USES PLATECOILS



as original equipment in their plating tanks

HERE'S WHY

Original equipment manufacturers looking for ways to add sales advantages to their machines without adding to their cost have been quick to standardize on **Platecoils**. The **Crown Rheostat and Supply Co.**, Chicago, Illinois, has joined the rapidly growing list of **Platecoil** users with the following results: "The quality workmanship of **Crown** equipment calls for the installation of only the ***best accessories*** and **Platecoil** easily enters into this group of items ***acceptable to a discriminating plating trade.***

"**Platecoils** are advantageous because of their space-saving qualities and high efficiency plus the fact they are so easily cleaned and maintained. **Crown Rheostat and Supply Co.** finds it advantageous to use **Platecoils in partially automatic** and **fully automatic** plating machines, barrel plating and still tank equipment."

You, too, will find that **Platecoils** provide better heat transfer for only a fraction of the cost of pipe coils. Engineering and estimating take less time. Installation is simplified and less costly.

Get the complete story on Platecoil savings. Send today for your copy of the new bulletin P74 telling how "Platecoils" overcome the limitations and high cost of pipe coils for ORIGINAL EQUIPMENT MANUFACTURERS. There is no obligation.

PLATECOIL
Division
KOLD-HOLD MFG. CO.
LANSING 4, MICHIGAN

mospheric pressure. Because the carbon dioxide is under higher pressure, some of it passes through the plate and enters the other side of the test chamber where oxygen carries it to a carbon dioxide absorption tube.

Amount of carbon dioxide which passes through the test plate depends on the porosity of the plate. Weight of the gas collected during a measured period of time provides a basis for calculating the leakage rate through the plate.

◆

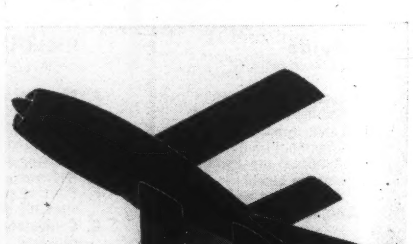
Taft-Peirce Mfg. Co., Woonsocket, R. I., recently appointed Russell Shepherd as sales representative in the New England territory for standard products and contract manufacturing activities.

Remote Control Guides Jet Target Plane

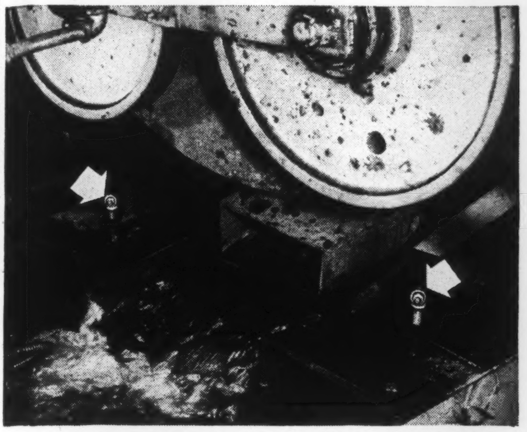
Guided by a ground pilot at a remote control panel, the Ryan Q-2 pilotless target plane travels at near sonic speed. This jet-propelled drone is less than half the size of modern American jet fighters, but its performance is claimed to be comparable.

With sharply swept wings and tail surfaces, the Q-2 is designed for antiaircraft and aerial gunnery training and for use in combat plane interception problems by Army, Navy and Air Force units.

Artist's conception of Q-2 pilotless, jet-propelled target drone. Silhouette drawing released with approval of the Department of Defense reveals a minimum of design, dimensional and performance information

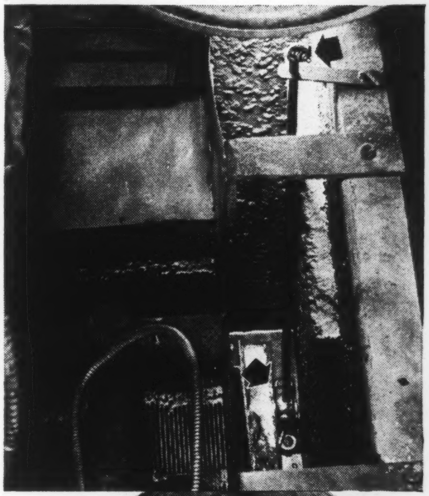


12 months "Snorkel" duty... and still in excellent condition



↑ Relubrication fittings for Fafnir Pillow Blocks are indicated by arrows. Once-a-week lubrication plus Fafnir Mechani-Seals protect submerged bearings.

↓ Complete installation shows relubrication fitting, pipe and Fafnir Pillow Block.



Standard Fafnir Ball Bearing Pillow Blocks

On a conveyor used for lifting steel balls from the water quench bath of a rotary type furnace are two 1½" Fafnir LAK Type Ball Bearing Pillow Blocks. These bearing units, running at 2-3 r.p.m., are three feet under water. The water bath has a pH of about 6 and a temperature automatically controlled at 90°F.

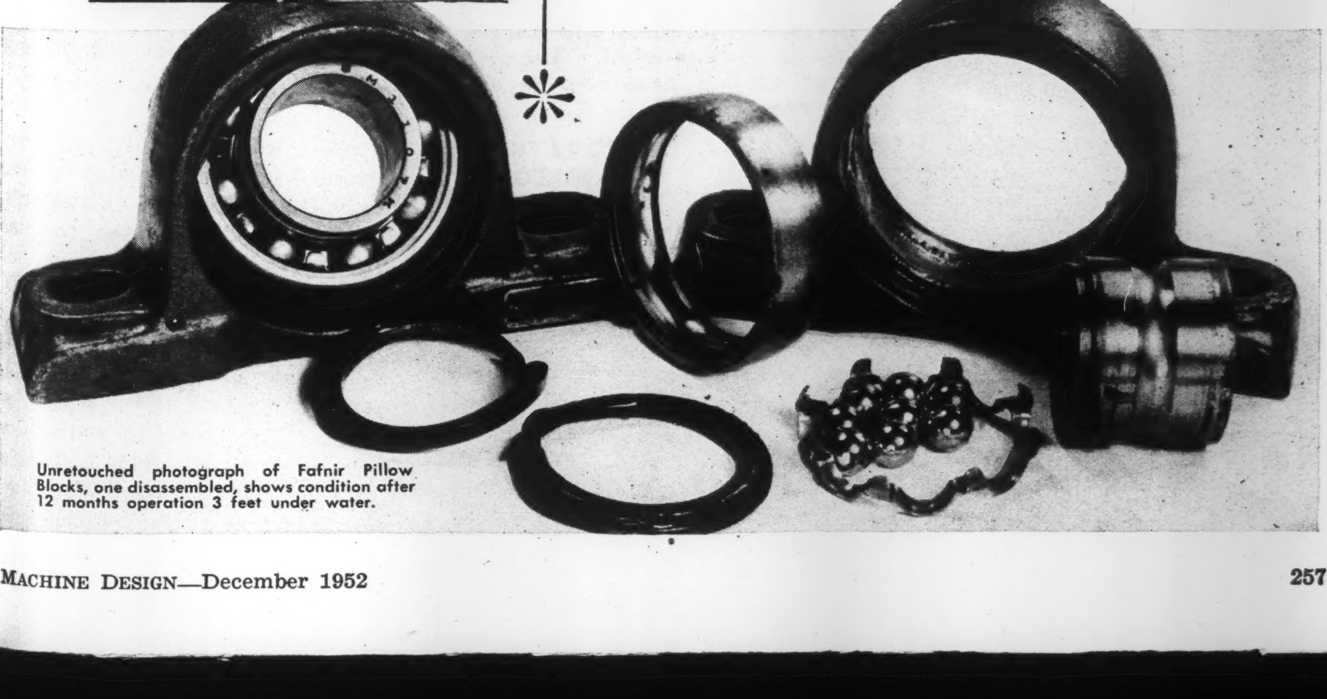
After 12 months of operation at 16 hours a day, 6 days a week, the pillow blocks were removed for inspection. Their condition is shown in the unretouched photograph below. According to a maintenance report, both the pillow blocks and bearings were in excellent condition and suitable for further service.

This application may help you to find a better, cheaper way to use bearings. Although it's unusual . . . it serves to demonstrate the multiple-uses of Standard Fafnir Ball Bearing Units plus their ability to operate efficiently under extreme conditions. Whatever your bearing problem, a few minutes spent with a Fafnir representative may help you solve it as successfully. The Fafnir Bearing Company, New Britain, Conn.

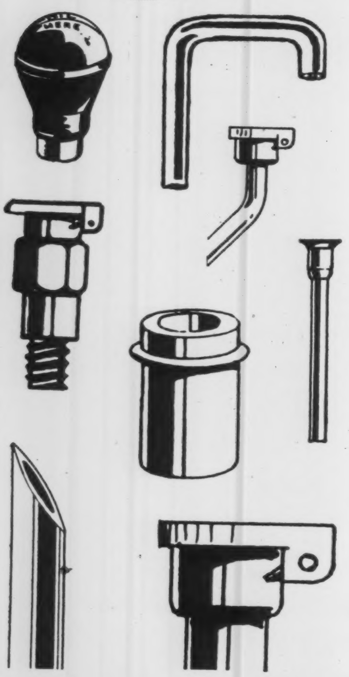
FAFNIR

BALL BEARINGS

MOST COMPLETE LINE IN AMERICA



Unretouched photograph of Fafnir Pillow Blocks, one disassembled, shows condition after 12 months operation 3 feet under water.



EDCO

DO YOU USE

Oilers

OR

FORMED TUBING?

Stocks of standard oilers and oil cups as listed in our new catalog are now carried at our factory in Detroit. Complete manufacturing facilities are available for your requirements for special oilers and lubricating devices.

Our facilities for both high volume and small quantity runs of special tube forms are at your disposal. We shall be pleased to quote, submit samples or aid in design of any oiling devices or special formed tube parts, the following being a few of the many tube parts we can make:

Spacers	**Oil Lines**
Bushings	**Tube Assemblies**
Vent Tubes	**Orifice Tubes**

Write for our new catalog today.

EYNON-DAKIN CO.

9901 Freeland Ave., Detroit 27, Michigan

The PERFECT SEAL

DURAMETALLIC

Packings

For thirty five years, custom-built types and styles of Durametallic Packings have been serving the various stuffing box requirements of the chemical industry. . . .

Durametallic Sales and Service is nation-wide. Submit your sealing problems to us for free counsel.

DURAMETALLIC CORPORATION
KALAMAZOO,
MICHIGAN

Engineering News

Standardization Program Effects Savings

An intensive standardization program, coupled with engineering improvements in certain General Electric aircraft instruments, has reportedly saved the government "hundreds of thousands" of dollars. Prices on certain aircraft instruments being supplied to military aircraft have been reduced by more than 20 per cent.

Typical of the standardization process is the GE aircraft instrument generator. The number of models of this instrument was reduced from 102 to 2, and the price dropped from $28 to $22 per instrument. Similarly, an aircraft speed indicator used on jet planes, once produced in 260 different models, is now available in only 11 models. Price has been reduced from $110 to $90.

The standardization program was accomplished after surveys showed that a small percentage of the aircraft instrument models produced could, if properly applied, satisfy all requirements. This made possible the elimination of many models, varying only slightly from others in design and construction, which had formerly prevented mass production.

◆

The firm name and address of Albert Trostel & Sons Co. has been changed to **Albert Trostel Packings Ltd.**, Lake Geneva, Wis.

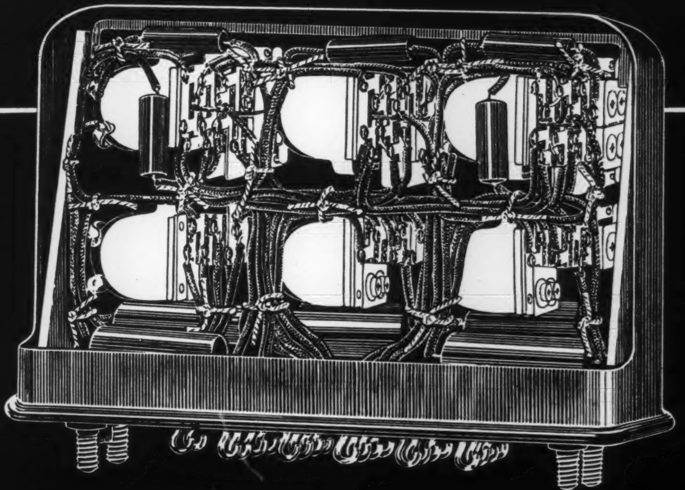
◆

B. F. Goodrich Chemical Co. has named Tom B. Nantz as manager of its new vinyl plastic monomer plant at Calvert City, Ky.

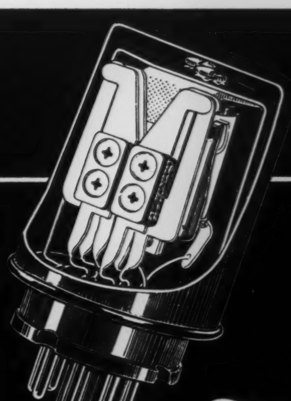
◆

Robert A. McLaughlin, recently appointed director of sales for the Fiber Glass Div. of **Pittsburgh Plate Glass Co.**, Pittsburgh, has announced the establishment of two new sales offices. Paul D. Kaley is district sales manager of a new office in New York, with headquarters at 30 Rockefeller Plaza, and H. J. Bygott Jr. is Washington, D. C., manager at 1545 New York Ave., N. E. The division's first fiber glass plant recently began production at Shelbyville, Ind.

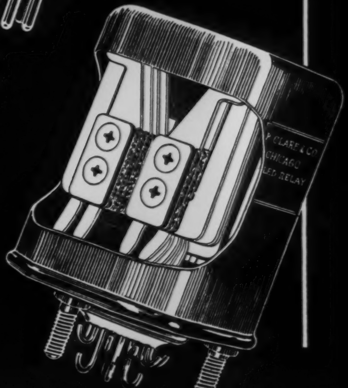
CLARE offers the widest variety of HERMETICALLY SEALED RELAYS for most exacting design requirements!



Considerable cost and space can often be saved by sealing more than one relay in an enclosure. Illustration shows six CLARE Type "K" relays, associated resistors and capacitors, wired and mounted in a common enclosure.



Here is one of over 300 plug-in relays in the CLARE SK-5000 series.



CLARE Type "N" relay in a Series SN-41000 container.

What CLARE Hermetic Sealing Means:

After assembly in the container, the enclosure is attached to a high vacuum pump and pumped down to a few microns pressure to remove all traces of moisture and gases, then flushed with dry nitrogen, and again pumped down.

While under this extreme vacuum, the enclosure and seals are tested for leaks by means of a Mass Spectrometer—a device so sensitive that it can detect a leak so tiny that more than thirty-one years would be required for one cubic centimeter of air to pass through it. This highly refined method of leak testing causes rejection of many enclosures which could pass the usual immersion tests without detection.

For most applications, the enclosure is then filled with dry nitrogen, which has a relatively high arcing potential.

IN THE fourteen years since CLARE first began the development of hermetically sealed relays for airborne, military and industrial use, CLARE has developed over 50 different series of hermetically sealed relays.

Each series varies in the size of the container, the number and kind of terminals, mounting facilities and the type or types of relays which can be sealed in it. Within each series, innumerable variations of relay coil and contact specifications are possible.

Two things, however, never vary: the high quality of the CLARE relay which goes into each enclosure and the completely airtight sealing which permits no gas or spirit to escape from the enclosure or enter it.

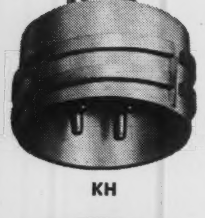
If your product requires the use of hermetically sealed relays, CLARE can supply you just the relay you need from this wide variety, or will develop and seal for you a special, "custom-built" relay to meet your most exacting requirements.

Send for CLARE BULLETIN NO. 114 on Hermetically Sealed Relays or contact the nearest CLARE sales engineer for complete information. Address: C. P. Clare & Co., 4719 West Sunnyside Avenue, Chicago 30, Illinois. In Canada: Canadian Line Materials Co., Ltd., Toronto 13. Cable address: CLARELAY.

CLARE RELAYS

...First in the Industrial Field

CANNON PLUGS for hermetic sealed applications

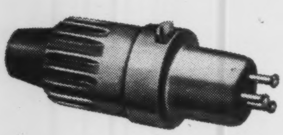


KH

RKH

HERMETIC SEALED Type RKH Plugs and KH Receptacles mate with their corresponding Cannon RK and K standard fittings. The basic construction of fused vitreous insulation around the contacts is same as GS type. Shell materials and finish are likewise similar. Various types of flange or hex-bulkhead styles may be made to order.

Refer to KH-1 Section in K Bulletin.



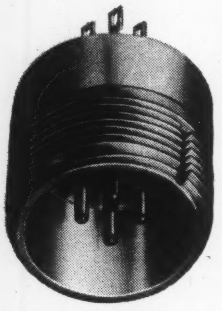
SUB-MINIATURE receptacles of the new Cannon "U" Series are used on miniature switches, relays, transformers, amplifiers, and other sealed components, requiring a true hermetic seal or a connector of sub-miniature size with performance superiority.

"U" plugs have a steel shell and "SILCAN*" insulator, cable relief and moisture resistant sleeve.

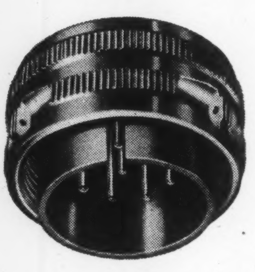
Bayonet-type locking means prevents vibration failure. Rated 1700v. d.c.; 5a. Available in 3, 6, and 12 contact arrangements with one plug style and two receptacles.

**Cannon Electric's special silicone resilient material.*

Refer to U-2 Bulletin



GS02



GS06

GS Types mate with standard AN(MIL) types. These highly successful hermetically sealed plugs (GS06) and receptacles (GS02) pioneered this field and are top quality fittings. Fused vitreous insulation provides a true hermetic seal for relays, position indicators, etc. Shells are steel, finished in cadmium plate and bleached Iridite; coupling nut on plug is natural finish Dural. Eyelet or solder pot terminals.

Built to resist thermal shock, −300°F. to +600°F., surpassing MIL Spec. GS02 Types will withstand operation temperatures 400°F. to 600°F., and pressures as high as 200 to 900 psi; specials to 7500 psi. GS Types approximate AN voltage and current ratings. Wide range of AN layouts available.

See GS-3 section in AN-8 Bulletin for details.

COMING: TYPE "DH" HERMETIC SEALED CONNECTORS SIMILAR TO PRESENT DA-15P

CANNON ELECTRIC

CANNON ELECTRIC

Since 1915

Factories in Los Angeles, Toronto, New Haven, Benton Harbor. Representatives in principal cities. Address inquiries to Cannon Electric Co., Dept. L-185, P.O. Box 75, Lincoln Heights Station, Los Angeles 31, Calif.

Engineering News

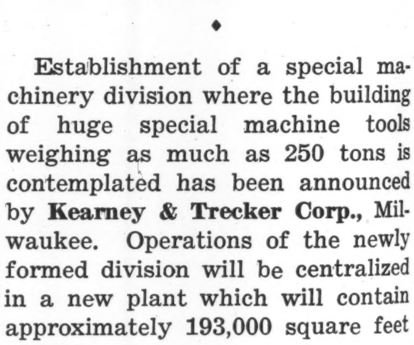
Educators Study Plant Operations

To study actual manufacturing operations and consider the management and economic problems confronting industry, teachers, principals and directors of education from the schools of New York State recently visited the plant of Lamson Corp. This visit was part of the training program of the Workshop on Economic Education sponsored by Syracuse University and the Joint Council on Economic Education.

The group studied improvements in processes and quality and resulting cost considerations, as well as advancements in working conditions for employees. The tour thus enabled the visitors to acquire first hand information concerning the true economics of machines—how they create jobs, raise the standard of living, reduce physical effort and affect employment in related fields.

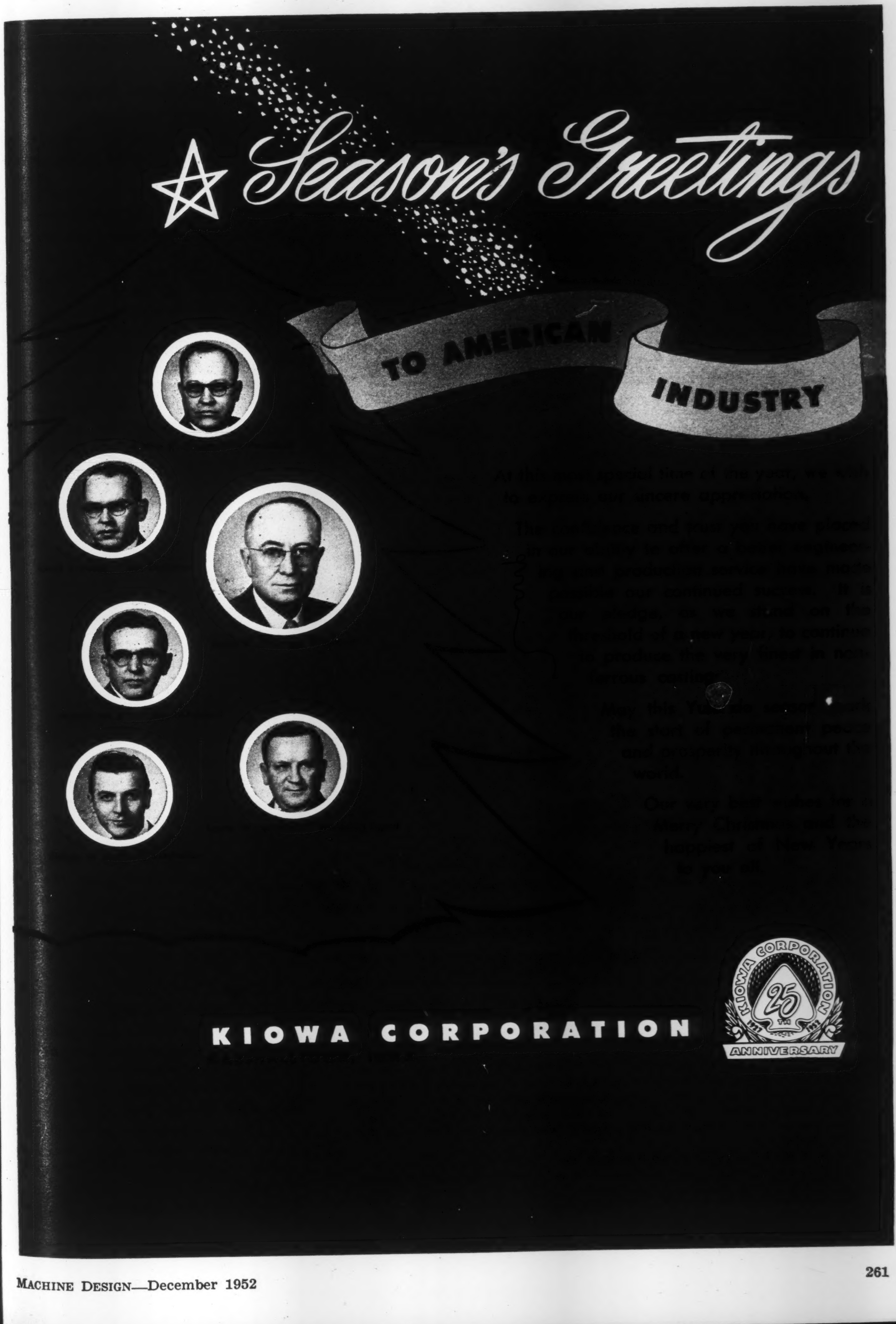
◆

Establishment of a special machinery division where the building of huge special machine tools weighing as much as 250 tons is contemplated has been announced by **Kearney & Trecker Corp.,** Milwaukee. Operations of the newly formed division will be centralized in a new plant which will contain approximately 193,000 square feet of space.



ENGINEERING-DESIGN & DEVELOPMENT DEPT.
Chief Engineer
I DON'T KNOW!
Glueck

"Obviously he doesn't want to be disturbed."



Season's Greetings

TO AMERICAN INDUSTRY

At this most special time of the year, we wish to express our sincere appreciation.

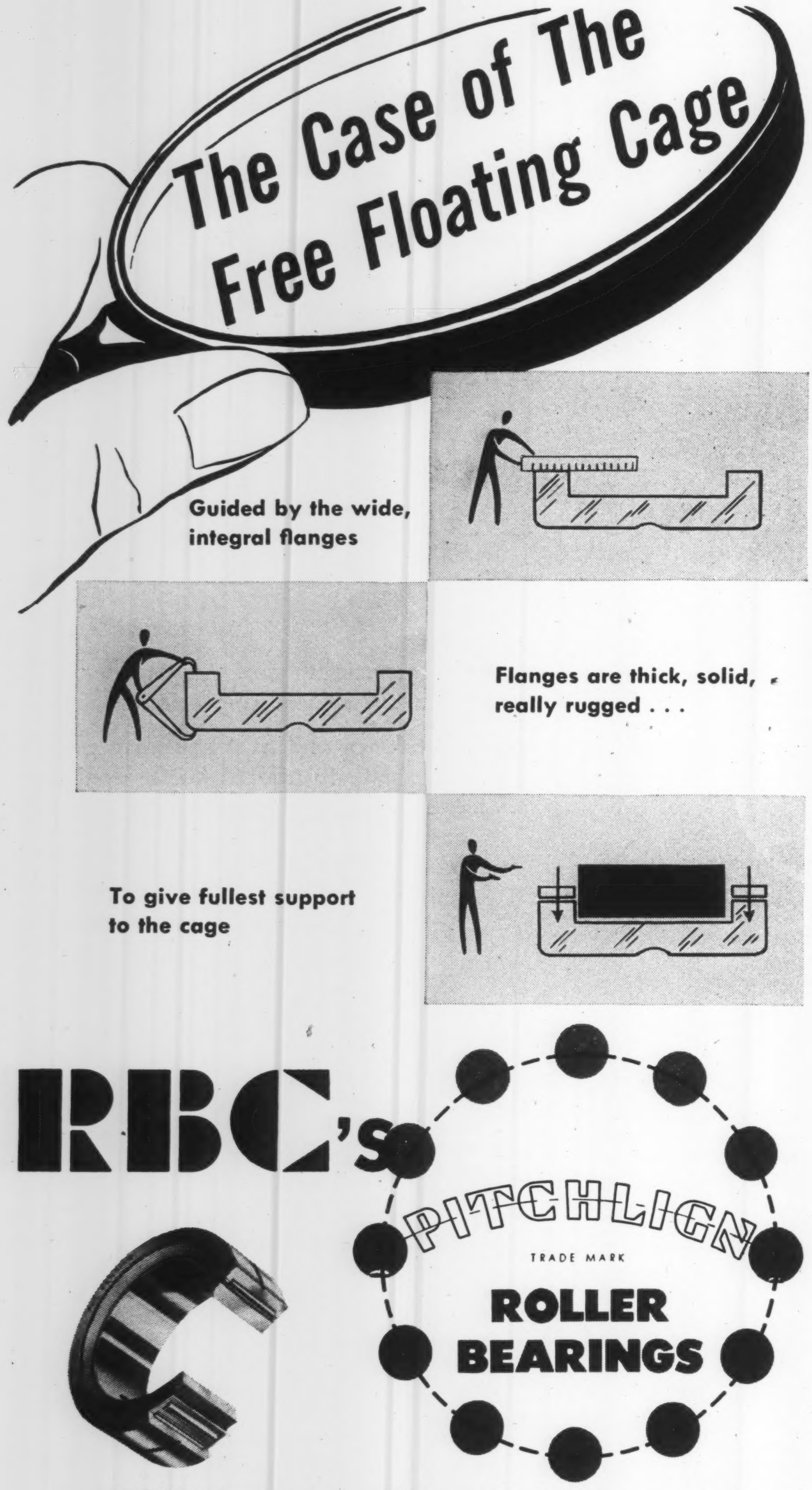
The confidence and trust you have placed in our ability to offer a better engineering and production service have made possible our continued success. It is our pledge, as we stand on the threshold of a new year, to continue to produce the very finest in non-ferrous castings.

May this Yuletide season mark the start of permanent peace and prosperity throughout the world.

Our very best wishes for a Merry Christmas and the happiest of New Years to you all.

KIOWA CORPORATION

KIOWA CORPORATION 25TH 1927 1952 ANNIVERSARY


The Case of The Free Floating Cage
Guided by the wide, integral flanges
Flanges are thick, solid, really rugged . . .
To give fullest support to the cage
RBC's
PITCHLIGN
TRADE MARK
ROLLER BEARINGS

PITCHLIGN bearings have a full length, free floating cage with *pitch circle contact!* Any tendency of the rollers to thrust is absorbed by the heavy integral flanges of the outer race. Completely relieved of this burden, the cage *cannot* distort and so fail in its vital duty of roller alignment. This is the one positive method of doing away with cocking and skewing. Only PITCHLIGN has it!

PITCHLIGN performs where others fail . . . interchangeable with precision needle bearings, of course. Get the facts! *Ask for Bulletin SF-266*

RBC
ROLLER BEARING COMPANY OF AMERICA • TRENTON, N. J.

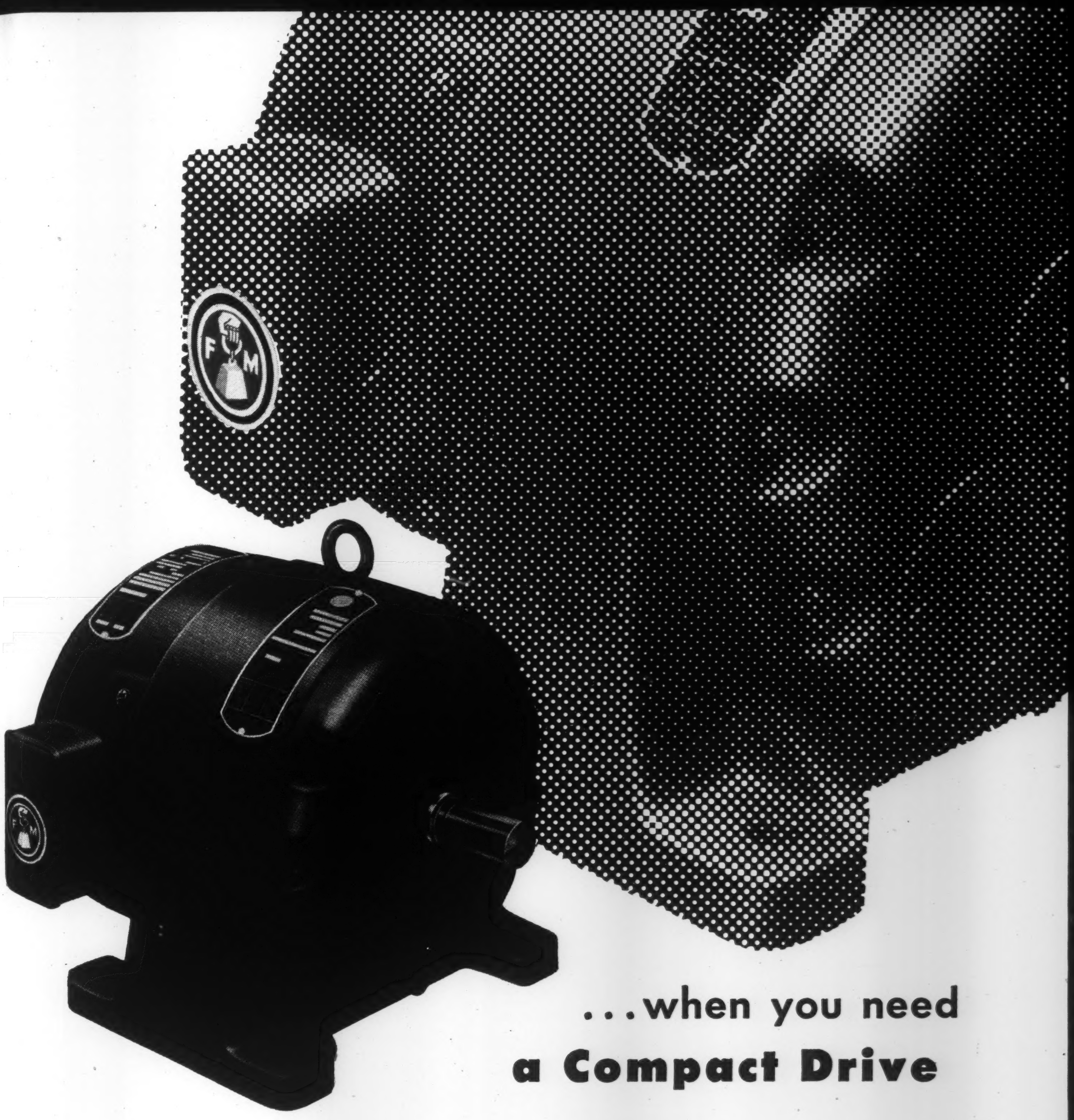
New Thin-Metal Standard

A 1952 revision of the American Standard, *Preferred Thicknesses for Uncoated Thin Flat Metals (Under* 0.250 *In.)*, B32.1-1952, has been approved by the American Standards Association. It was developed by ASA Committee B32 on Wire Diameters and Metal Thicknesses, jointly sponsored by the American Society of Mechanical Engineers and the Society of Automotive Engineers. In the new standard, increments in sheet-metal thickness from 0.004 to 0.236-inch are in accordance with the 40-series of preferred numbers, amounting to about three per cent increments. The new standard, therefore, gives the designer a wider choice of thicknesses. Some of the values added in the new standard are identical with, or close to, thicknesses contained in the gage-number systems.

Report on Materials

Washington will probably sit tight until the expiration of production controls on June 30, although continual easing of many materials will be evident. Traditionally, there is a reluctance of lame duck officials to take action so, until the new administration takes office, not much can be expected to occur. Price controls, which expire April 30, will probably be allowed to lapse, especially since the CIO has now officially come out against their continuance. But production controls may continue on a standby basis after June 30, possibly as an extension of CMP on a reporting basis. Some provision will have to be made to insure placement of basic military orders, and possibly this too might be incorporated into some type of voluntary priority setup.

The continued easing of materials—except aluminum — is noticeable in many quarters. A supplemental 1.48 million pounds of carbon steel products was allotted for the first quarter of 1953, although faster use of third and fourth quar-



. . . when you need a Compact Drive

. . . look for the Fairbanks-Morse Seal. On slow-speed applications, for example, you'll find the unique F-M Motorgear that combines reduction gears with the 40%-Shorter Axial Air Gap Motor to make a complete slow-speed unit—*more compact than the average motor alone!*

Whatever the drive problem on your equipment, the Fairbanks-Morse Seal is your assurance of top performance, minimized servicing . . . symmetrical design that improves appearance of the driven unit.

When you look for motors—one or a thousand . . . for standard or unusual applications—*always* look for the Fairbanks-Morse Seal. For over 120 years that seal has stood for the finest in manufacturing integrity to *all* industry. Fairbanks, Morse & Co., Chicago 5, Ill.

WITH ANOTHER

FAIRBANKS-MORSE

a name worth remembering when you want the best

ELECTRIC MOTORS AND GENERATORS • DIESEL LOCOMOTIVES AND ENGINES • PUMPS
SCALES • HOME WATER SERVICE EQUIPMENT • RAIL CARS • FARM MACHINERY • MAGNETOS

VELVAGLAZE
NOW OFFERS NEW
Design Opportunities

...Highlight your product appeal

These new low cost Velvaglaze Finishes capture the gleaming brightness that highlights product appeal. They offer greater surface durability and resistance to scratching, discoloration and stain.

Many unusual finish designs are available through Monarch's exclusive Velvaglaze Process. These designs cut casting costs by eliminating multiple finishing operations. They reduce rejects now encountered on highly polished, easy to mar surfaces.

Velvaglaze Finishes offer you an additional bonus when you specify Monarch aluminum Permanent Mold Castings and aluminum Diecastings. Consult with a Monarch engineer on all of your casting and finishing requirements. He will give you complete information on the specific Monarch service that meets your individual need.

*T. M. Reg. U. S. Pat. Off.

Monarch

- Aluminum Permanent Mold
- Aluminum Die Castings
- Certified Zinc Die Castings
- Complete Product Assembly
- Every Modern Finishing Service

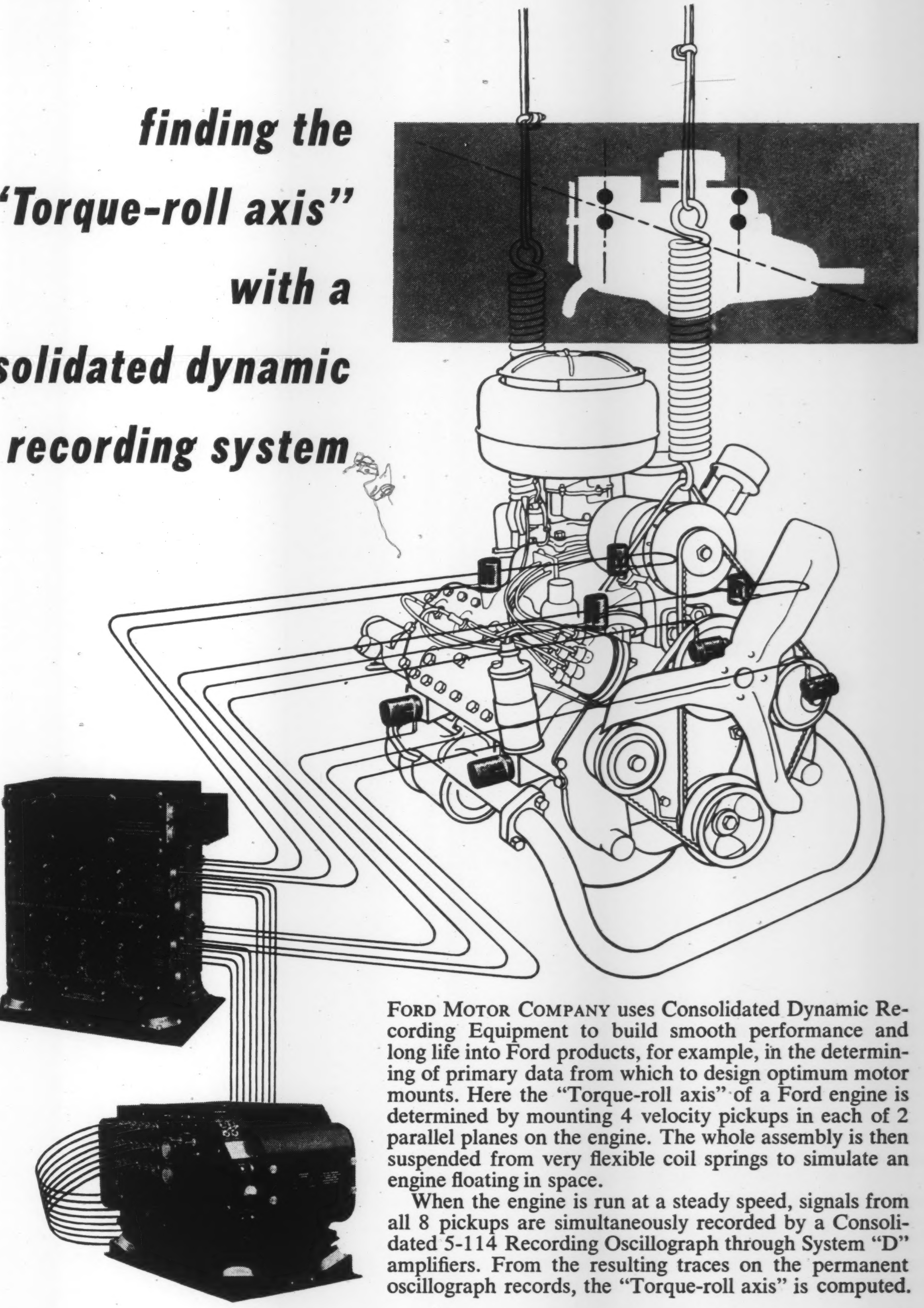
Detroit Ave. at W. 93rd St., Cleveland 2, Ohio

ter allotments accounts for much of this revision in plans. Automatic allotment limits on the procurement of steel controlled materials have again been raised, this time to 100 per cent of the total quantity of carbon, alloy and nickel-bearing stainless steel used in the third quarter of 1953.

Civilian products, however, will receive the same allotment of aluminum and copper in the first quarter as in the fourth quarter. Steel will be restricted to 33 per cent of base-period usage for most types; aluminum will be 55 per cent; and copper 50 per cent. Shortage of steel is explained by NPA officials as a secondary effect of the steel strike. Although enough steel will be available for military and defense-supporting goods, little will be left over. This situation may not be too serious, however, since steel plants are rapidly cutting down their civilian order backlogs, and carryover orders from November and December may actually add to the amount available. In aluminum, effect of the power shortage in the Pacific Northwest and Tennessee Valley is felt.

Concern Over Aluminum: The aluminum situation, especially in the first and second quarter of 1953, is causing some concern. Power shortages are causing a loss of almost 25 per cent of national primary aluminum production, or about 40 million pounds a month. Thus, at the end of the fourth quarter of 1952, the aluminum industry will have an order backlog of upwards of 150 million pounds, meaning a delay of four to six weeks in meeting customers' orders. As temporary means for alleviating the situation, producers have requested the government (1) to defer stockpiling until the order backlog reaches 100 million pounds, (2) to withdraw some aluminum from the stockpile to help tide consumers and fabricators over a period of temporary shortage and, (3) to attempt to get additional aluminum from Canada and abroad. This last suggestion is actually being followed, since Aluminum Company of Canada is doubling their ingot shipments during the first quarter,

finding the "Torque-roll axis" with a Consolidated dynamic recording system



Ford Motor Company uses Consolidated Dynamic Recording Equipment to build smooth performance and long life into Ford products, for example, in the determining of primary data from which to design optimum motor mounts. Here the "Torque-roll axis" of a Ford engine is determined by mounting 4 velocity pickups in each of 2 parallel planes on the engine. The whole assembly is then suspended from very flexible coil springs to simulate an engine floating in space.

When the engine is run at a steady speed, signals from all 8 pickups are simultaneously recorded by a Consolidated 5-114 Recording Oscillograph through System "D" amplifiers. From the resulting traces on the permanent oscillograph records, the "Torque-roll axis" is computed.

Consolidated Engineering
CORPORATION
300 North Sierra Madre Villa, Pasadena 15, California

Sales and Service through **CEC INSTRUMENTS, INC.,**
a subsidiary with offices in: Pasadena, New York, Chicago,
Washington D.C., Philadelphia, Dayton.

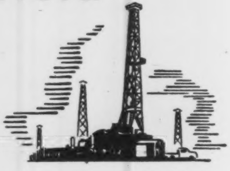
analytical
instruments
for science
and industry

Dynamic Recording Systems

such as the one shown here have infinite variations in application and in the arrangement of the equipment. A typical recording system includes pickups, amplifiers, and a recording oscillograph. Write for Bulletin CEC 1500B.

In the shop —

In the field —



a new kind
of lubricant

Moly-sulfide is a tenacious solid-film lubricant with remarkable properties under extreme pressure, high velocity and fretting conditions. Many new uses for *Moly-sulfide* are being found every day in the shop and the field.

We have compiled 154 case-histories of successful applications of molybdenum sulfide to solve a wide range of industrial and technical problems; these are published in a form most useful to those who want practical information on what has already been accomplished by this new kind of lubricant.

Send for your free copy of *Moly-sulfide: In The Shop—In The Field,* a 40-page booklet of up-to-date information.

Moly-sulfide
A LITTLE DOES A LOT

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New York City·36·N·Y

Moly-sulfide

Please send me
your Free Booklet

Name.............................
Position.............................
Company.............................
Address.............................

MOLY

MD12 MS 5A

an added supply of 77 million pounds.

Canadian Nickel Boosted: Presently on the "most critical" list, nickel supplies will get a substantial boost by the addition of supplies from two Canadian sources. More than 4 million pounds of nickel, as well as considerable amounts of copper and some platinum and palladium, will be produced by two mines annually. In 1950, the United States consumed nearly 200 million pounds, and demand has increased since then.

Titanium Expansion Goal: A revised expansion goal for titanium "sponge" metal has been announced by DPA. Closely matching the rapid upswing of interest in the metal, the revised goal calls for production of 22,000 short tons in 1955, an increase of 12,000 tons over the original goal established in June of this year.

In 1950, titanium sponge production amounted to 500 tons, and the projected 21,500-ton expansion is for defense purposes. Since numerous potential civilian uses exist, DPA has scheduled the present goal for possible further revision within the next six months.

Basic Materials and Alternates: Rapid comeback of the steel industry is reflected in somewhat easier supplies of carbon bars and plates. seamless tubing, die blocks and light castings. The "most critical" designation has been withdrawn from cold-drawn carbon bars, hot-rolled bars and semifinished steel, plates, and seamless tubing. DPA officials point out that this softening reflects more than just recovery from the steel strike, since three of these items have been listed in this category for more than eight months. Plastics have also had a considerable change. Most have been removed completely from the list, including:

Cellulose acetate
Cellulose butyrate
Methacrylate
Phenolic resins
Polyester resins
Polystyrene
Polyvinyl acetate
Polyvinyl alcohol
Polyvinyl butyral
Melamine resins
Polyvinylidene chloride and copolymer resins
Urea resins

This list is abstracted from List No. 9, released October 31. Com-

PUMPS

FOR COOLANTS,
LUBRICANTS, AND
ABRASIVE LIQUIDS

PUMPS

POSITIVE DISPLACEMENT
AND
IMPELLER TYPES

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J. I. C. STANDARDS
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DEPENDABLE,
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STANDARD OR SPECIAL,
FOR EVERY MACHINE TOOL
AND INDUSTRIAL USE

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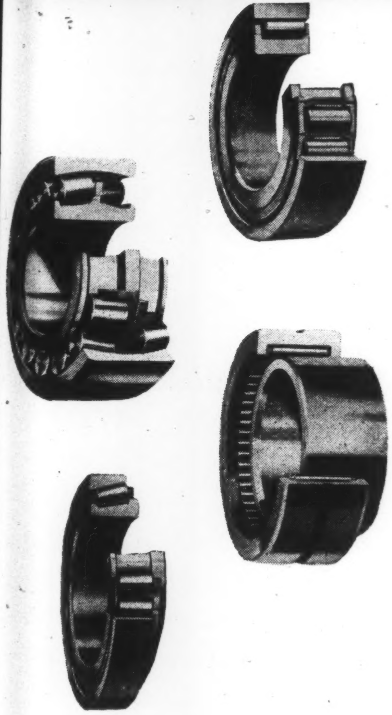
Pioneer
PUMP
& MANUFACTURING CO., INC.

19652 JOHN R STREET
DETROIT 3, MICHIGAN

WRITE FOR CATALOG

over-all service...



The responsibility of the Torrington engineer does not end with a recommendation for a particular type of anti-friction bearing. He makes every effort to "follow through" to see that the bearing continues to give the best possible performance, with a minimum of maintenance.

Over-all service—starting with the original design and continuing through in-service operation—has helped to produce the *lasting* solution to the friction problems of many manufacturers. Why not discuss *your* application with a Torrington engineer today?

THE TORRINGTON COMPANY
South Bend 21, Ind. Torrington, Conn.
District Offices and Distributors in Principal Cities of the United States and Canada

TORRINGTON BEARINGS

Spherical Roller • Tapered Roller • Straight Roller • Needle • Ball • Needle Rollers

GET THIS BULLETIN

WHETHER IT'S ORIGINAL EQUIPMENT DESIGN OR CHANGING OVER TO AIR, YOU MAY SAVE ENORMOUSLY BY STANDARDIZING ON . . .

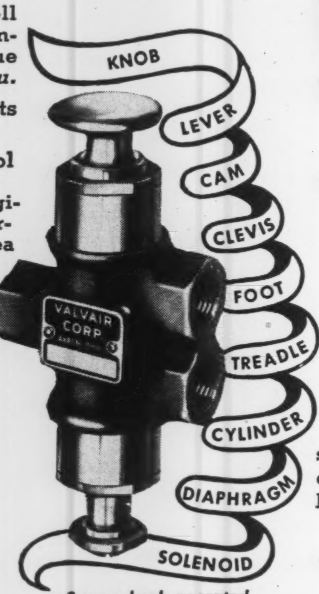
Eight pages, well illustrated, outlining Valvair's unique advantages *for you.*

The bulletin starts thus:

"Valvair air control valves are the expression of an original, exclusive, perhaps ingenious idea in design and construction.

"The objective: To meet virtually countless requirements with fewer types of valves than ever before," etc.

Your letterhead request will be answered promptly.



3-way, knob-operated air control valve.

VALVAIRS

Thanks to Diversatility

★ ★ ★

ESPECIALLY ADAPTED TO TOOLING AND FIXTURE DESIGN

★ ★ ★

● Valvair Diversatility is an exclusive, original form of standardization. Five basic bodies permit incorporating any one (or two) control assemblies with a standard valve body. Unique Valvair advantages enable us to speed your order at no extra cost. . . Sizes: 1/4" through 1". May we fill your orders *now?*

Get new Bulletin "D-12".

VALVAIR CORPORATION
Affiliate: Sinclair-Collins Valve Co.
953 BEARDSLEY AVE., AKRON 11, OHIO

REPRESENTATIVES IN PRINCIPAL CITIES

Rely Upon Valvair 3-WAY 3-WAY 3-WAY

BIG or SMALL

UP TO 16" O.D. . . . . . DOWN TO 5/16" O.D.

SPECIAL

ANTI FRICTION BEARINGS ARE ROUTINE BUSINESS FOR US

ROLLER, BALL OR NEEDLE

Your requirements for SPECIAL Anti Friction bearings may look tough to fill, but we'd welcome the chance to look them over.

Morton Bearing Company has handled some mighty difficult ones in the past.

QUANTITIES . . . from one to thousands.

SIZES . . . from 5/16" to 16" O.D.

SPECIAL RADIAL, THRUST or ANGULAR CONTACT bearings made to meet specific customer requirements of load, speed or space limitations.

No matter how unusual, how exacting your specifications may be, SEND THEM TO US FOR SPEEDY QUOTATION AND DELIVERY ESTIMATE. No obligation of course.

MORTON TYPES OF SPECIAL and STANDARD THRUST BEARINGS

Flat Races—
Grooved Races—
Flat Seats—
Spherical Seats—
Banded Ball—
Double Direction—
• Extra Light •
• Light • Medium •
• Heavy Series •

MORTON BEARING COMPANY
200 HILL STREET
Ann Arbor, Mich.

SEND NEW CATALOG OF STANDARD ANTI-FRICTION BEARINGS
Name
Firm Name
Products Manufactured
Street City State

BALL BEARINGS AND ROLLER BEARINGS

plete copies may be obtained from Printing Services, Department of Commerce, Washington 25, D. C., or from any district or regional office.

Metals—Group I-A
(In short supply)

a—Nonferrous:
  Beryllium
  Selenium (all grades)
  *Titanium
b—Precious:
  Platinum
c—Ferrous alloying elements:
  *Cobalt
  *Columbium
  *Molybdenum
  *Nickel
  *Tantalum
  Tungsten
d—Ferrous:
  Bars, cold drawn:
    Alloy
    Carbon steel
  Bars and semi-finished, hot-rolled:
    Alloy
    Carbon steel
  Castings:
    *Gray iron: Heavy, over 3,000 pounds
    *Gray iron alloy: Heavy over 3,000 pounds
    Carbon steel
    *Carbon steel: Heavy, over 3,000 pounds
    High alloy steel:
      Corrosion-resistant
    Heat-resistant
  Castings:
    Low alloy steel: Heavy over 3,000 pounds
  Forgings, heavy
  Iron powder
  Pig iron, low phosphorus
  Pipe:
    Seamless, all sizes
    Welded: 4 inches and over
  Plates
  Rails
  Shapes, structural
  Sheet:
    Cold rolled
    Galvanized
    Hot rolled
  Strip:
    Cold rolled
    Hot rolled
  *Stainless steel: Nickel bearing
  Strandwire, galvanized
  Tubing, seamless:
    Alloy mechanical
    Alloy pressure
    Carbon, mechanical
    Carbon, pressure

Metals—Group II-A
(In approximate balance)

a—Nonferrous:
  Aluminum
  Calcium
  Copper
  Magnesium
  Tin
b—Precious:
  Iridium
c—Ferrous alloying elements:
  Chromium
  Manganese
  Vanadium
d—Ferrous:
  Castings:
    Carbon steel, under 3,000 pounds
    Low alloy steel, under 3,000 pounds
  Forgings, medium
  Pig iron (other than in Group I)
  Pipe, welded: 3 inches and under
  Plate, tin
  Rods: Hot rolled
  Wire, drawn: Welding quality

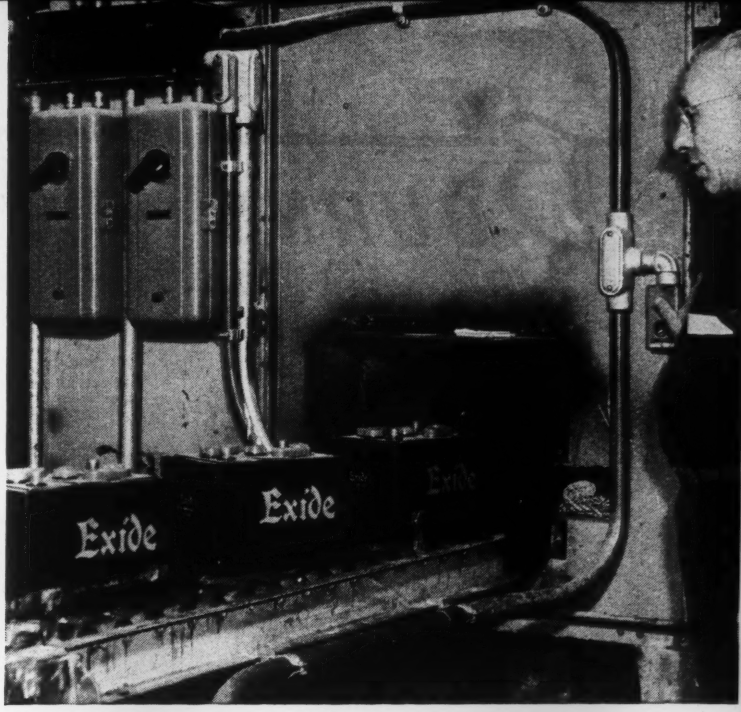
Metals—Group III-A
(In fair to good supply)

a—Nonferrous:
  Antimony
  Bismuth
  Cadmium
  Germanium
  Lead
  Mercury
  Tellurium
  Zinc
b—Precious:
  Gold

---

*Most critical.

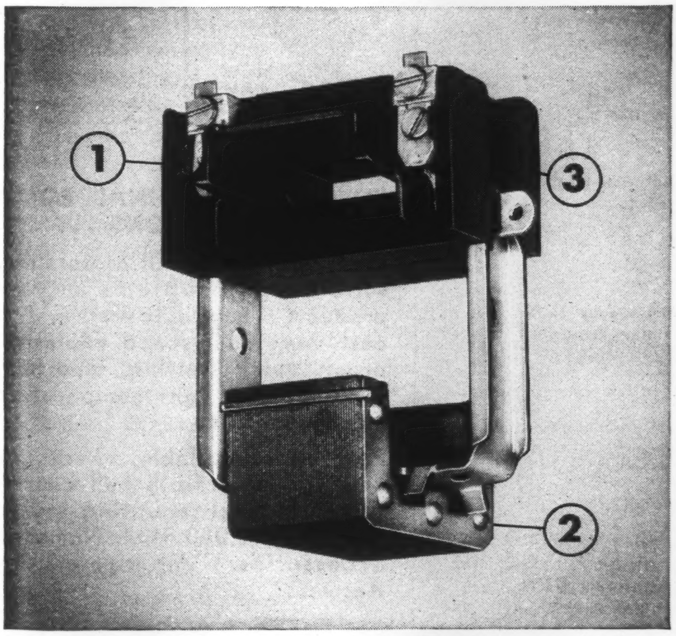
ELECTRO-LIFT, INC. of Bloomfield, N. J. makes motorized hoists which are subject to continual start-stop operation. They use G-E magnetic starters to assure unfailing operation to their customers, and to speed their own production. Ample wiring room and large pan-head screws, all in front, mean fast and easy installation.



THE ELECTRIC STORAGE BATTERY CO. of Philadelphia, Pa., makers of Exide Batteries, chose G-E magnetic motor starters to protect production flow. They report no shutdowns due to starter failure. Above, two General Electric fusible combination starters are used in key section of an Exide production line.

Leading industrial plants report:

"G-E Magnetic Starters keep production up!"



LONG LIFE is built right into the heart of G-E starters: the tough G-E *strongbox* coil (1). Winding is sealed in solid, molded plastic; dust, oil, moisture sealed out. This coil cannot be damaged by a maintenance man's screwdriver. Movable magnet of silicon steel (2) moves in straight line in permanently lubricated guides (3). Many other features assure long, *dependable* operation.

Electro-Lift, Inc. and the Electric Storage Battery Co. have joined the thousands of companies who use G-E magnetic motor starters to maintain top production.

They know that dependable G-E starters give longer-lasting protection against shutdowns. Exclusive G-E features assure millions of starts and stops—even under tough conditions, varying loads.

LOW MAINTENANCE

One big reason these companies chose G-E starters is low maintenance, year after year. The only tool needed is a screwdriver. Silver-tipped contacts are easy to inspect and remove—may be interchanged without adding parts. Captive lockwashers, screws, and terminal clamps save time, make maintenance easier.

WIDEST VARIETY

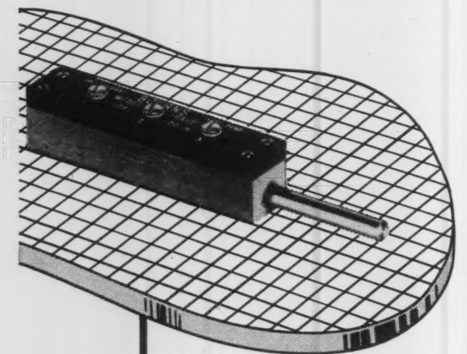
General Electric manufactures the most complete line of motor starters. You have your choice of all NEMA sizes in general-purpose, watertight, dust-tight and explosion-proof enclosures. It's easy to add interlocks in G-E starters—change contacts from normally-open to normally-closed—change coils.

FAST DELIVERY

You can get G-E starters right off the shelf by contacting your nearest G-E Apparatus Sales Office or authorized distributor. For more information send for bulletin GEA-5781. Address Section 730–40A, General Electric Company, Schenectady 5, N. Y.

GENERAL ELECTRIC

BOURNS



LINEAR
MOTION
POTENTIOMETERS

BOURNS precision wire-wound potentiometers accurately translate mechanical position into an electrical signal. Resolution of .001 inch attainable in all standard ranges from 1 to 6 inches. Technical publication describing standard models and special applications available upon request.

BOURNS designs and manufactures other potentiometer instruments which measure such physical variables as gage pressure, differential pressure, altitude and acceleration.

BOURNS
LABORATORIES
6135 MAGNOLIA AVENUE
RIVERSIDE, CALIFORNIA

- Osmium
- Palladium
- Rhodium
- Ruthenium
- Silver

c—Ferrous alloying elements:
- Boron
- Calcium-silicon
- Ferrotitanium
- Silicon
- Zirconium

d—Ferrous:
- Castings:
  - Gray iron alloy, light-weights
  - Gray iron (light and intermediate weights)
  - Iron, malleable
- Die blocks
- Forgings, small
- Nails
- Netting
- Plate, tin mill black
- Stainless steel: Straight chrome
- Tool steel
- Tubing, welded: Carbon mechanical
- Wire, drawn (other than in Groups I and II)

Chemicals—Group I-B

(In short supply)

- Alkyl and aromatic substituted phenolic resins
- Lithium metal
- Nickel chemicals
- Paraphenylphenol
- Paratertiary butyl phenol
- Polymonochlortrifluorethylene
- Selenium compounds (from electrolytic copper sludges)

Chemicals—Group II-B

(In approximate balance)

- Alkyl polysulfide polymers
- Butadiene

Chemicals—Group III-B

(In fair to good supply)

- Nylon, plastic type
- Polyethylene
- Polyethylene resins
- Polytetrafluorethylene (Teflon)
- Selenium compounds (other than Group I)

Miscellaneous—Group I-D

(In short supply)

- Asbestos:
  - Amosite
  - Chrysotile:
    - Crude and spinning fibers
    - Shingle fibers
  - Crocidolite
- Mica:
  - Muscovite block and film, good stained and better
  - Bookform splittings
- Rubber:
  - Natural, dry:
    - Pale crepe, grades IX-1

Miscellaneous—Group II-D

(In approximate balance)

- Graphite, natural:
  - Crucible flake
  - Ceylon: High carbon amorphous lump
- Mica:
  - Muscovite block and film (lower than good stained)
- Quartz crystals (MBS Grades I and II)
- Rare earths
- Refractories:
  - Chromite
  - Silicon carbide

Miscellaneous—Group III-D

(In fair to good supply)

- Asbestos, Chrysotile: Shorts and waste fibers
- Mica:
  - Phlogopite, splittings
- Refractories:
  - Dolomite
  - Fire clay
  - High Alumina
  - Magnesite
  - Silica
  - Sillimanite
- Rubber:
  - Butyl (GRI)
  - Synthetic (GRS)
    - Cold
- Talc:
  - Ground, including steatite
  - Indian block, lava grade

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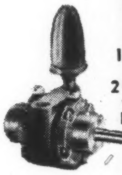

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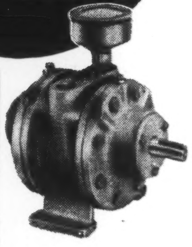

Model 8 AM
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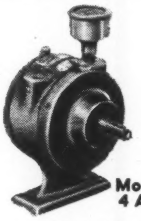
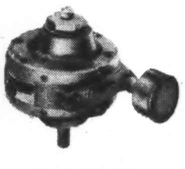


Model 4 AM
Up to 1 H.P.—only 5¾" high (less muffler).



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Stress Relief

ENGINEERING a product and designing a report have been compared as processes requiring the same kind of thinking in the ead article of this issue, Page 114. Now, J. P. Henderson augments the points so clearly brought out in that article by offering some candid observations and pertinent recommendations on the personal viewpoints and attributes involved.

Genius at Work

In years past, it has been my doubtful privilege to hire a number of project or development engineers. Like any new employee, each arrival represents a gamble. Is he aggressive enough to get things done? Will he fit into the organization? Will he merely display a batch of technical information with which he will tackle the jobs given him, or does he really know what is involved in being a development man?

I have found so many who failed to realize the important requirements of development that the qualifications could well be discussed at length. Men carrying the title of project, development or experimental engineer vary in ability from the highly mathematical genius to the experimental tinker with practical techniques. Depending upon the job and the organization, that can all be well and good.

But nearly all of them fail in one respect—*reports* and *records*. And their importance cannot be over-emphasized.

Look at the most disorderly desk and laboratory work bench. Look through a file folder on the desk. Are there unintelligible sketches, equations and tables jumbled together without identification? If so, you can depend on it, you have located the headquaters of the experimental engineer.

Of course, such a man must have a few facts explained to him and

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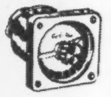

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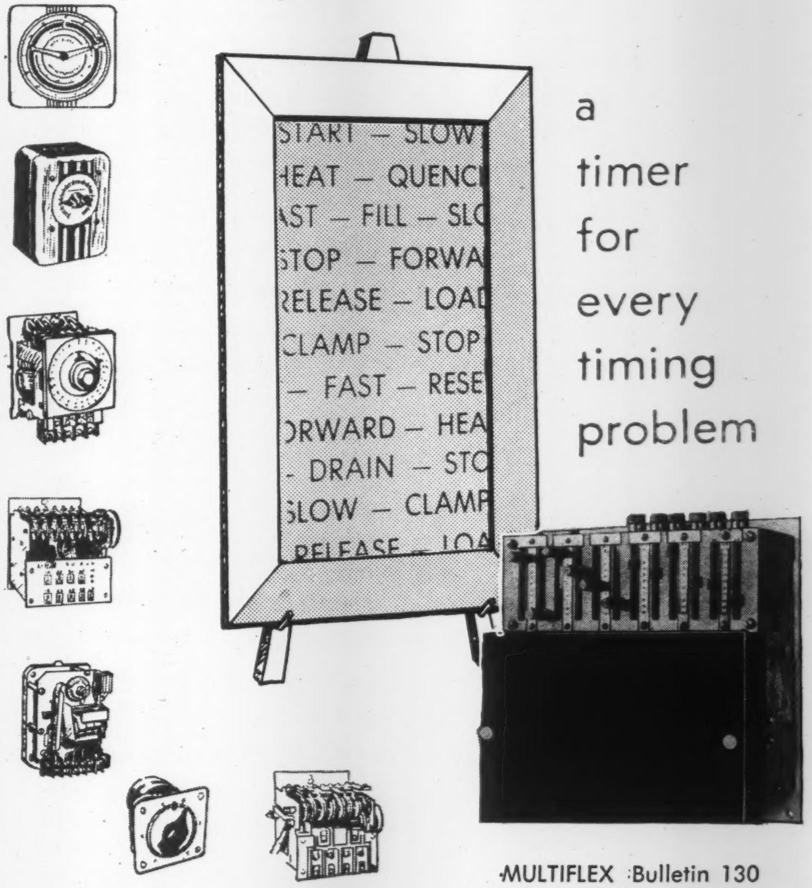

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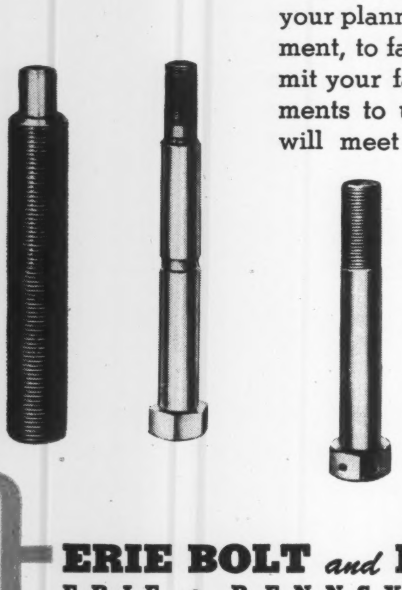

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be scolded. But it has been my experience that this has to be done continuously and with too little effect. Furthermore, many such project men seem to resent the idea that they should do anything so routine as make out a report or leave an intelligent record.

Required reports are of three kinds. The first type is needed immediately or in the near future and gives definite information on a project. These are usually written for the boss or for a management group.

The second type are those written apparently for one's own record of an investigation. It may be no more than a record of nonroutine current work. I say "apparently for one's own record" for that seems to typify the average project man's attitude. Confronted by his mess he says "Oh, those are just some of my own notes" and thereby reveals himself as a naive individual. The point is that he owns no notes of his own. On company time, on company pay, on company work, *his notes* are company property and a part of the engineering file.

What he has written is not for himself alone, but should be so recorded that his not-so-brilliant successor, five years hence, can read and understand what he has done.

I remember vividly one project man who was given the job of investigating vibration in a special machine. The problem had been complicated enough so that ordinary methods of correction had failed. After some discussion, he suggested an idea which was tried. It worked. Duly impressed, I told him to be sure to write a complete report for the file so that others could apply his method in the future.

I failed in demanding that he show me his report, or asking him every week if it were finished. (After all, he was a grown person and such childish methods were not needed.)

Several years later, he moved on to greener pastures. When a similar problem arose, I put his successor on it, suggesting that he review the method worked out previously and apply it. The file folder revealed a few unintelligible test readings and nothing more!

This might seem to be a picayune case of one man's shortcomings. Yet it is more than that, for it typifies to a greater or lesser extent the common attitude of a development man.

The third type of report is the working record for possible patent purposes. Presumably some of the work done by an engineer might have patent possibilities. Many organizations require that a day to day record be kept in a notebook—ideas, investigations, tests, comments and conclusions. Signed and dated, such notebooks are a useful record for patent application or establishing priority in cases of litigation.

What a chore for a genius!

Yet, a little imagination on the part of the project man should show him that to management (who makes it possible for him to work on his delightful problems) his record may be more important than a whole bucketful of his technical knowledge. That should be obvious. But, I would hate to have to fight a case in court with the slipshod records I have found in some such books.

So much for the project man's notable shortcomings and the mention of some of the things he should do well. In addition, we might outline some of the other qualities that he needs:

1. The ability to organize his work and "his" file so that what he has done is an intelligent record for others, coherent enough so that his work and methods can be reproduced.

2. The ability to get things done. Seldom is a development man the complete Lone Ranger. Sooner or later at a stage in his work he must depend upon others. The knack of obtaining co-operation, of circumventing stone walls — all these are necessary in an effective person.

3. The temperament or imagination that appreciates that so long as a man is a member of an organization it is necessary that he work largely within the established routine and through existing channels. Adherence to system can be overdone at the expense of rapid

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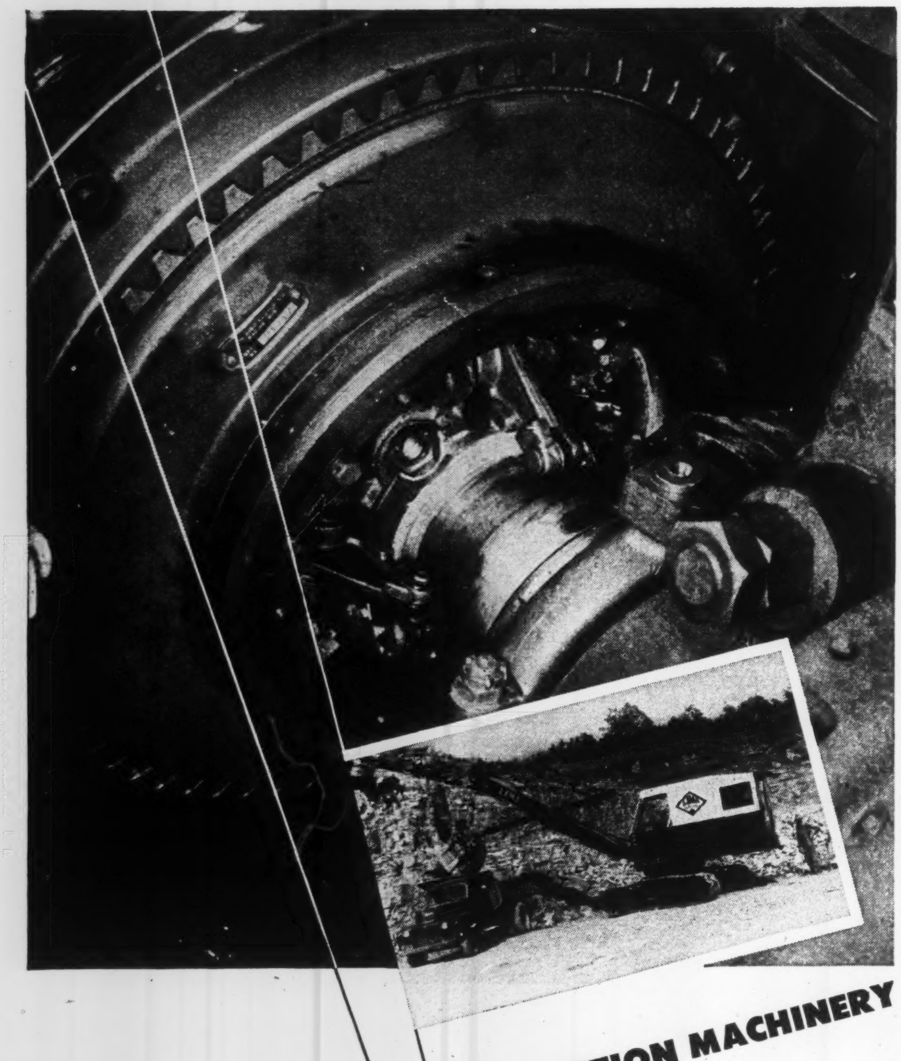

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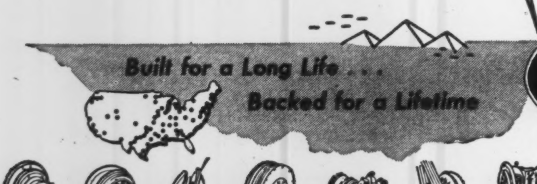

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progress, of course, but usually the original mind is in no danger of becoming ineffective through over-attention to office routine.

4. Childlike optimism. It has been said that the major result of a technical education is the talent to demonstrate how many things can't be done. A large enough development group might absorb one chronic doubter. But as an executive, how long would you put up with a project man whose initial reaction to every new job is "It won't work"? Such a man is not displaying erudition, but a lack of judgment. Too many things have been proved wrong—until they did work. The trouble is that many of our statements and equations describing natural phenomena are seldom complete. Under the proper circumstances, the neglected increment becomes the all-important factor which upsets the first hasty, conventional analysis.

5. Technical knowledge. It is not always the man who has the most formulas in his head who is outstanding on development work. Imagination may be more valuable than a walking handbook. Technical brains and great mathematical ability can be very useful in a project man, but I minimize their importance if not accompanied by the foregoing attributes. Looking at the problem of development from the standpoint of management, with a whole organization to think of, and established channels to operate through, I would be willing to trade two erratic geniuses with rough notes on the back of paper towels for one clever, orderly project man with a well-kept file.

—J. P. HENDERSON

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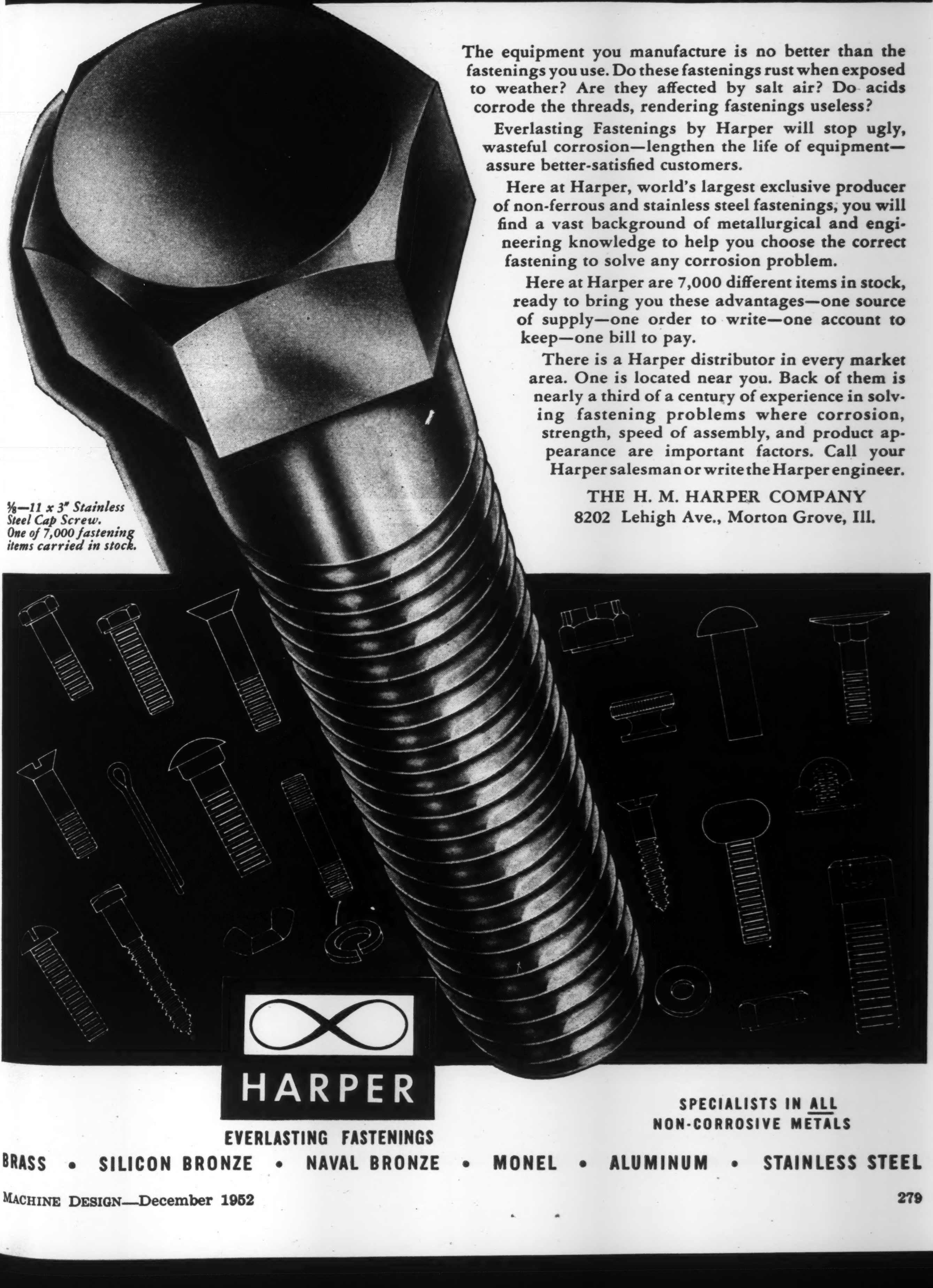

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Meetings

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Dec. 15-17—

American Society of Agricultural Engineers. Winter meeting to be held at the Edgewater Beach Hotel, Chicago, Ill. Raymond Olney, P. O. Box 229, St. Joseph, Mich., is secretary.

Jan. 12-15—

American Management Association. General management conference to be held at Hotel Statler, Los Angeles, Calif. Additional information may be obtained from society headquarters, 330 West 42nd St., New York, N. Y.

Jan. 12-16—

Society of Automotive Engineers. Annual meeting and engineering display to be held at the Sheraton-Cadillac Hotel in Detroit, Mich. Additional information may be obtained from society headquarters, 29 West 39th St., New York 18, N. Y.

Jan. 19-22—

Plant Maintenance Conference. Fourth annual conference to be held at the Public Auditorium in Cleveland, Ohio. Additional information may be obtained from the exposition management, Clapp & Poliak Inc., 341 Madison Ave., New York 17, N. Y.

Jan. 21-23—

Society of Plastics Engineers. Ninth annual technical conference to be held at the Hotel Statler in Boston, Mass. Additional information may be obtained from society headquarters, 409 Security Bank Bldg., Athens, Ohio.

Jan. 23—

Malleable Founders' Society. General society meeting to be held at Hotel Cleveland, Cleveland, O. Additional information may be obtained from society headquarters, 1800 Union Commerce Bldg., Cleveland, O.

Jan. 26-30—

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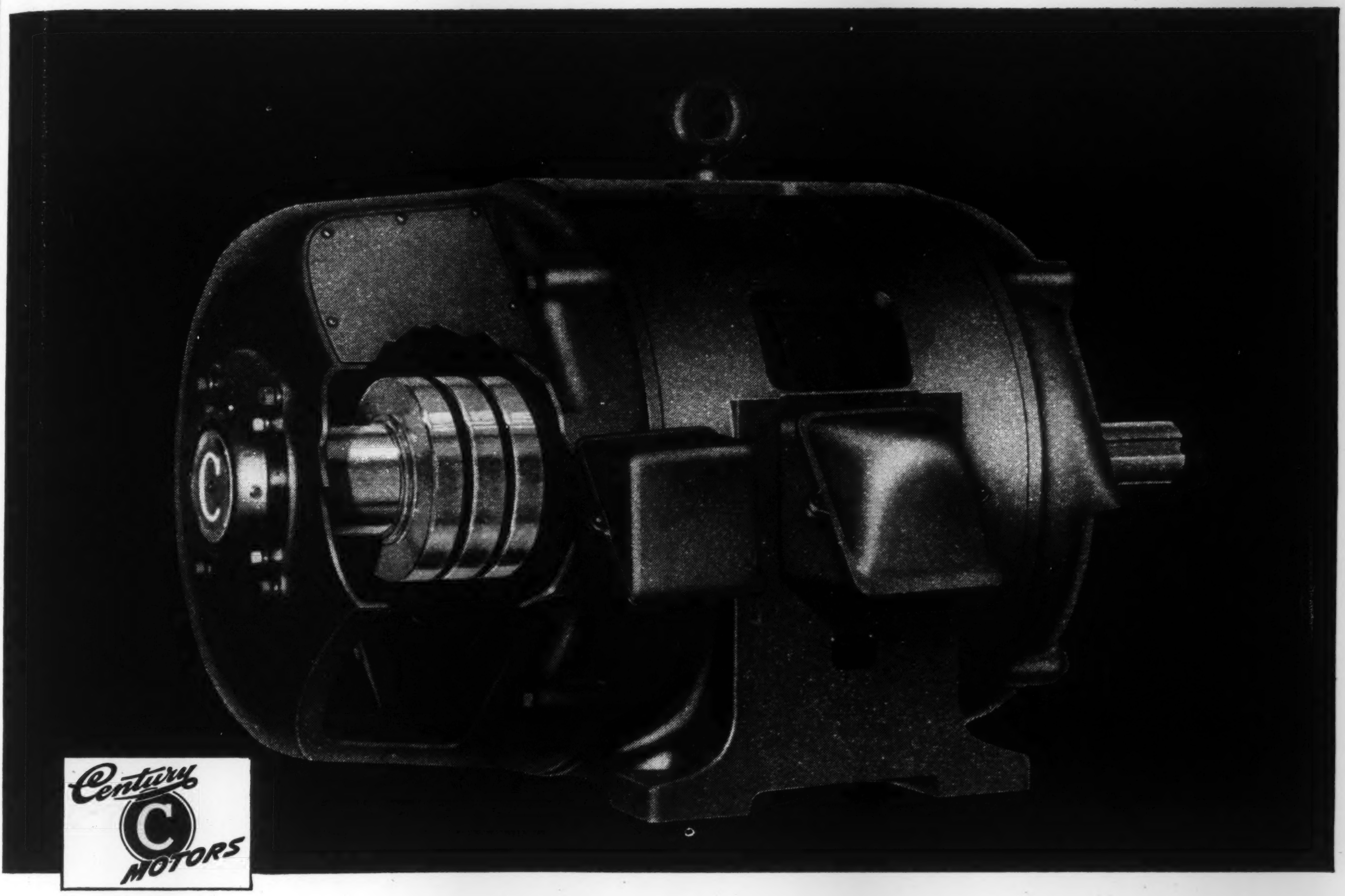

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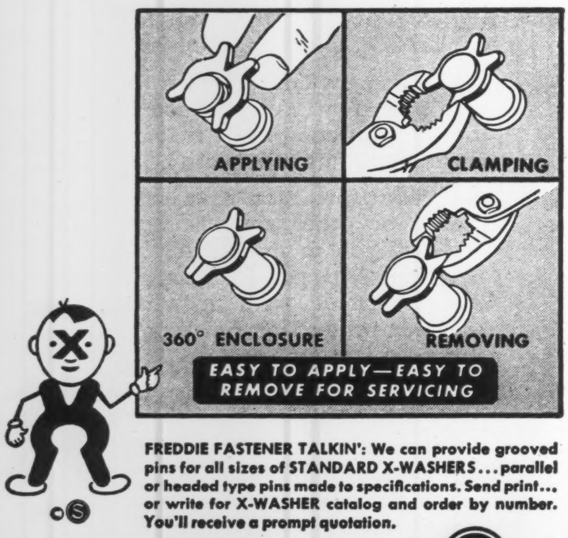

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Feb. 16-18—
American Management Association. Personnel conference to be held at the Palmer House, Chicago, Ill. Additional information may be obtained from society headquarters, 330 West 42nd St., New York, N. Y.

February 18-20—
Society of Plastics Industry. Eighth annual reinforced plastics division conference to be held at the Shoreham Hotel, Washington, D. C. Additional information may be obtained from society headquarters, 67 West 44th St., New York 18, N. Y.

Mar. 2-6—
American Society for Testing Materials. Spring meeting to be held at the Statler Hotel, Detroit, Mich. Additional information may be obtained from society headquarters, 1916 Race St., Philadelphia 3, Pa.

Mar. 3-5—
Society of Automotive Engineers. Passenger car, body and materials meeting to be held at the Sheraton-Cadillac Hotel, Detroit, Mich. Additional information may be obtained from society headquarters, 29 West 39th St., New York 18, N. Y.

Mar. 17-18—
Steel Founders' Society. Annual meeting to be held at the Edgewater Beach Hotel, Chicago, Ill. Additional information may be obtained from society headquarters, 920 Midland Bldg., Cleveland, O.

Mar. 31-Apr. 2—
International Magnesium Exposition to be held at National Guard Armory, Washington, D. C. Calvin H. Corey, 261 Constitution Ave., Washington 1, D. C., is general chairman.

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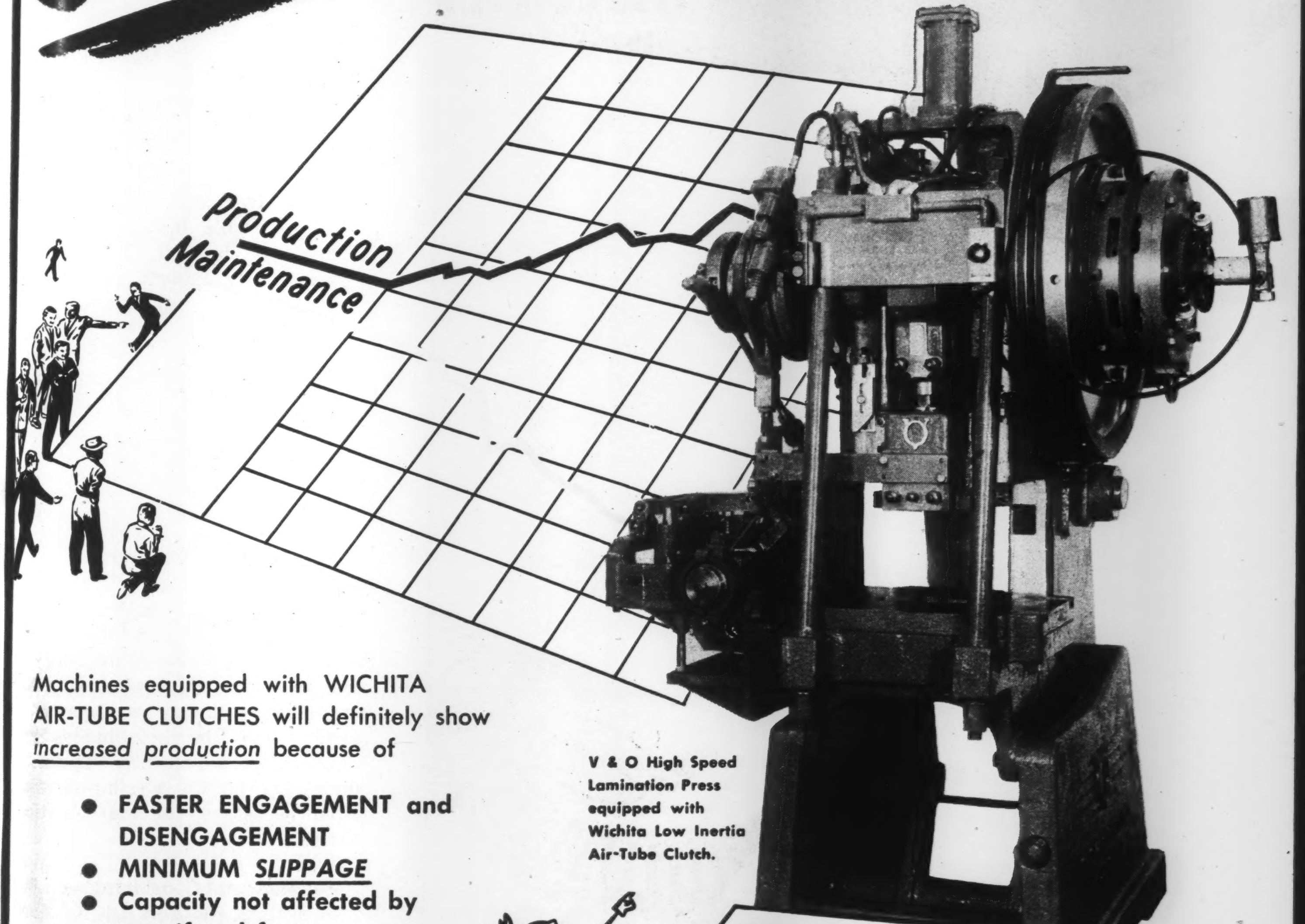

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Design Abstracts

(*Continued from Page* 191)

From a comparison with *Fig.* 1 *a* it can be seen that the source voltage and the potentiometer are the command and reference elements. The reference voltage obtained from the potentiometer is the reference input. This reference input is compared to the generator voltage by the feedback circuit and the difference appears across the input to the amplifier. In the block diagram a subtraction process is indicated between the reference input and the feedback from the controlled variable or the generator voltage. This voltage difference applied to the amplifier input is the actuating signal. The amplifier is the control element and its output voltage is the manipulated variable. The controlled variable is the terminal voltage as modified by the effect of load current flowing through the impedance of the generator armature.

Blocks in the diagram, *Fig.* 1 *b*, represent the physical characteristics of the system elements for the operating condition under consideration. Characteristics of the elements are usually assumed to be linear; that is, the generator saturation curve is a straight line, the amplifier is linear, no hysteresis occurs, and the inductances are simple lumped elements. These assumptions permit a simplification often necessary for mathematical analysis.

Fundamental Considerations: For this system, as for all feedback control systems, three important characteristics are of interest. These are accuracy, stability and damping, and response time. The term accuracy is used in several ways. Relative accuracy denotes how closely the controlled variable follows the reference. Absolute accuracy denotes how closely the controlled variable is maintained to an absolute value. Obviously, absolute accuracy is a function not only of the feedback control system and its elements but also the command and reference elements. Because of inaccuracies and nonlinearities in the latter elements, a

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Cabinet and knobs of this ultra-high-frequency TV converter are molded of **BAKELITE General-Purpose Phenolic BM-709.** Their rich maroon color and smooth durable finish present an excellent appearance.

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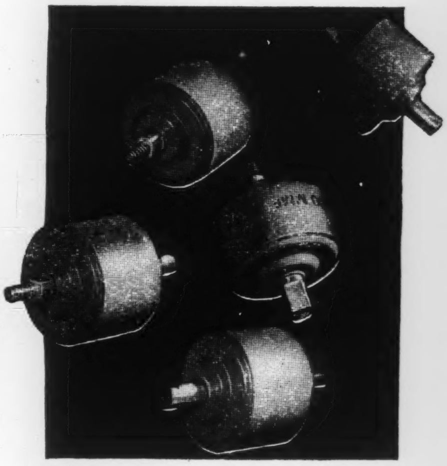


The insulating jackets on these high-voltage capacitors are molded of **BAKELITE Low-Loss Phenolic BM-17743.** They must withstand high temperatures and voltages, have low leakage and low power factor.

Made by Jeffers Electronics Division, Speer Carbon Co., DuBois, Pa.

Housing for Simpson Model 260 volt ohm milliammeter is made of **BAKELITE General-Purpose Phenolic BM-120.** It combines durability with smooth, attractive finish, lasting black color, and excellent electrical properties.

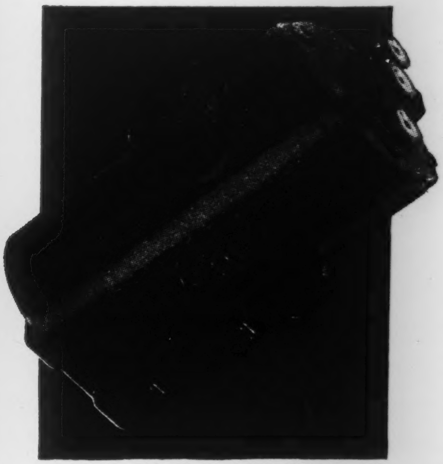
Made by Simpson Electric Co., Chicago, Illinois.

This welding gun handle of **BAKELITE High Impact-Resistant Phenolic BM-926** must withstand mechanical shock, heat of high-speed stud welding. By redesigning with phenolic plastics, overall weight was reduced 16 lb.

Molded by Plastic Research Products, Urbana, Ohio, for Nelson Stud Welding Division of Gregory Industries, Inc., Lorain, Ohio.

Molding this range switch base of **BAKELITE General-Purpose Phenolic BM-13838** reduced size, cut weight to one-sixth that of materials formerly used. Production and assembly are faster, more economical.

Made by Square D Company, Molded Insulation Division, Peru, Ind.



Ignition coil case molded of **BAKELITE General-Purpose Phenolic BM-14316** is moisture resistant, prevents "electrical choke." Coil produces up to 30,000 volts, must function between −80 deg. F. and 160 deg. F.

Molded by Detroit Molded Plastic Corp., Rochester, Mich., for D. S. M. Electric Co., Detroit, Mich.

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system having excellent relative accuracy can have poor absolute accuracy. Depending on the application, either or both may be important.

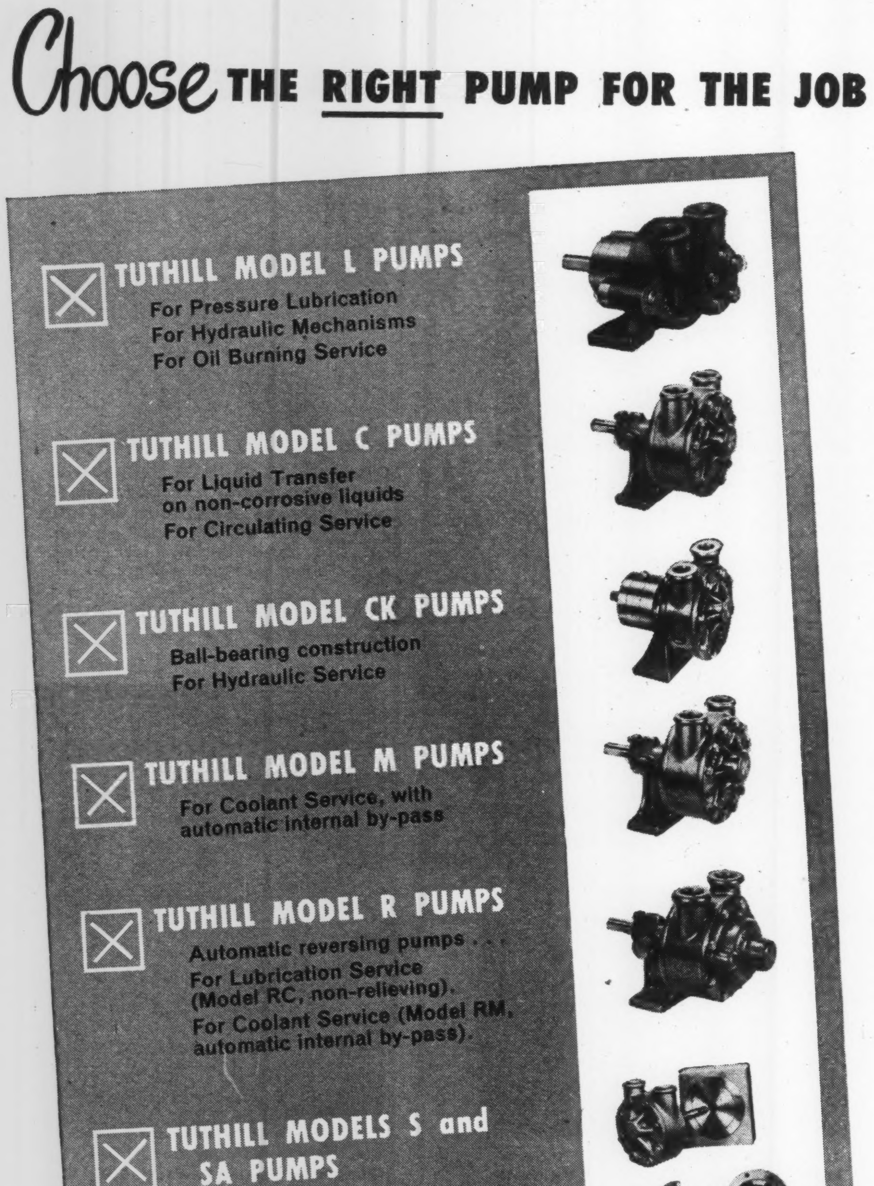
Stability and damping, which are terms used to describe the second important characteristic of feedback control systems, have precise meanings. A system is unstable if it will sustain continuous oscillations or build up destructive oscillations after a disturbance has been applied. A system is stable if such oscillations decay or damp out. This is a sharp dividing point. The term damping, however, is relative and is used to describe how quickly such oscillations decay.

Response time can be defined as several values. It may be the time required for the system output to reach a desired new value after an instantaneous change in reference input. Another important aspect is the time required to reach the correct value following a load disturbance. The particular characteristic of interest depends on the type of system and its application.

Types of Systems: One means of classification of systems is in terms of the controlled variable. Four groups can be established: (1) Voltage and current-control systems, (2) speed-control systems, (3) position-control systems, and (4) current, torque or load-limit systems. These, in general, are listed in the order of increasing complexity; however, accuracy and response characteristics more often determine system complexity.

Voltage and current systems are similar to the elementary system of *Fig.* 1, although they can be more or less complex. A speed system, *Fig.* 2, is also similar, except that it usually includes elements to convert the speed signal to a voltage. The tachometer generator is not necessarily a required element. A dc adjustable-voltage system using a voltage signal and an *IR*-compensation signal to obtain motor counter-emf is a speed-control system. Since a speed-control system involves a mechanical time constant it is usually more difficult to design and build.

Because position is the result of



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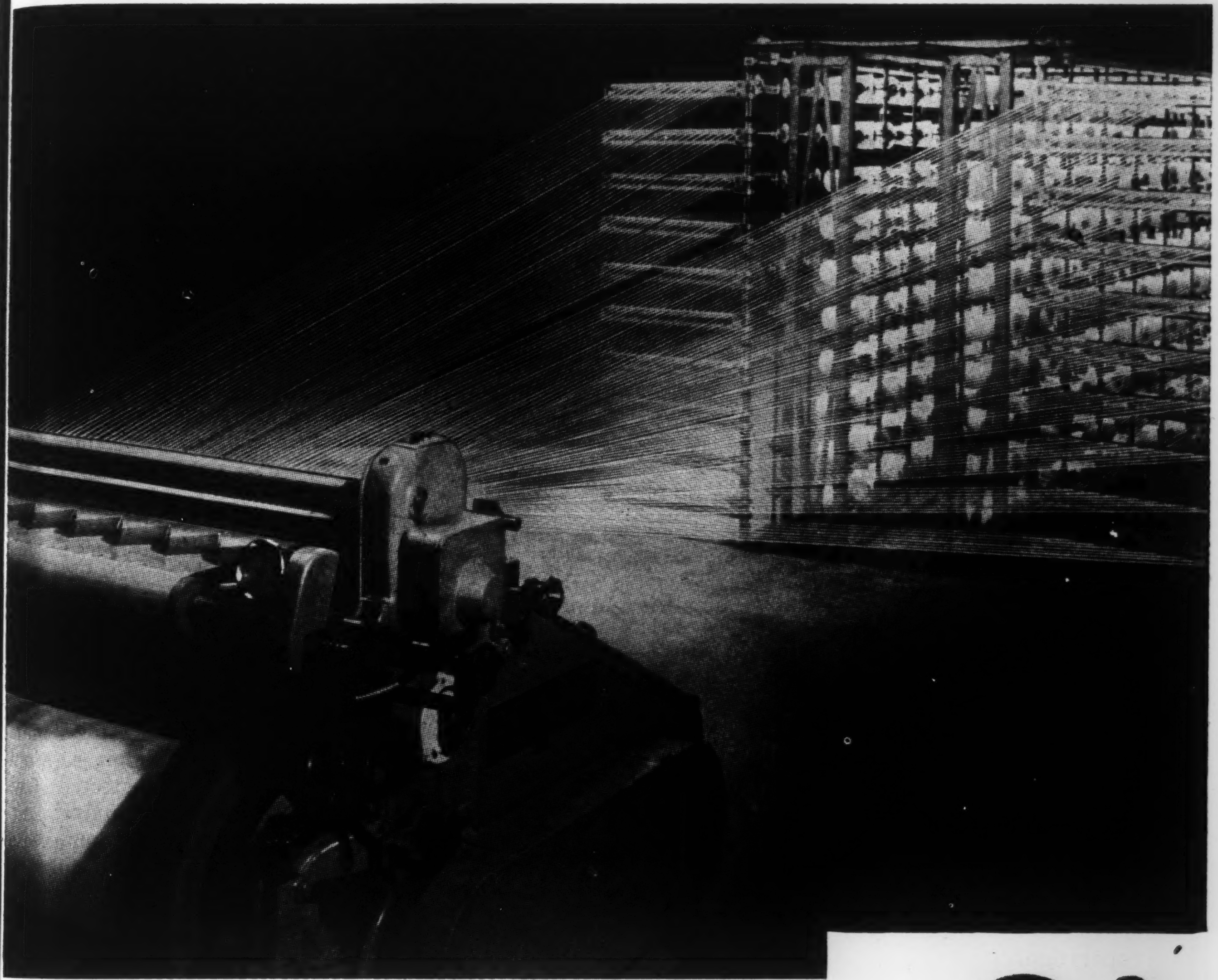

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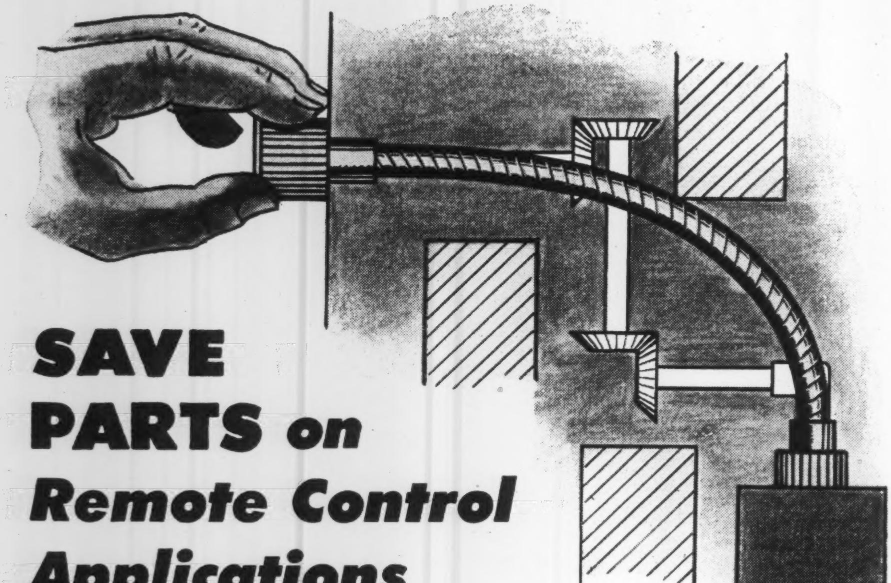

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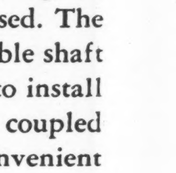

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an integrated velocity function, a position system, *Fig.* 3, can be considered as having one more time delay than a speed-control system. Thus, it is more complicated. However, since a position control permits obtaining perfect speed accuracy, a less complex system often can be obtained if a low-gain position control is used to replace an extremely high-gain speed control.

Limit-type systems, *Fig.* 4, are usually built to have zero output when the controlled variable is less than the desired value. Beyond this point their output is proportional to the quantity controlled and high gain is used to obtain sharp cutoff. Such systems are often superimposed on voltage or speed-control systems that have extremely high rates of forcing. Fast response can be obtained and, at the same time, the drive elements of the system can be maintained at their maximum safe output and yet be protected from damage by the limit control.

Many complexities and variations can be introduced into the circuits of these different systems to obtain the performance desired for actual applications. In the preceding discussion, the basic elements covered have been for "proportional" type control—controlled quantity is proportional to the actuating signal. Another important type is called "on-off" control. For this type no action occurs until the actuating signal has reached some definite value, at which point full correction is applied. A typical example is the home heat-control unit employing a thermostat system to turn a furnace on and off. Such systems are nonlinear and because of the relatively wide dead band or range over which no control is obtained, they have definite limitations as compared to proportional control.

Devices Used: Cataloging all the devices used as feedback control system components would be an impossible task. Included would be all the results of engineering art ranging from a simple spring to a fission-product beta-ray source. However, a thorough knowledge of all components used in a system is essential. The feedback-control system is usually only as good as the performance of the weakest component; compensating for the lack of a component is difficult.

AMPLIFIERS: For industrial applications some components have been used widely. The dynamoelectric or rotating amplifier is rugged and no more complicated than an ordinary dc machine. Reversible dc power can be supplied and isolation of input signals can be obtained by using a number of field windings.

The electronic amplifier has high input impedance and can operate from very low control power. It is often used when the actuating signal is obtained from phototubes and other low power devices. Development of more rugged tubes and components has increased the number of industrial applications. A push-pull arrangement, required to obtain reversible dc power, is a disadvantage because it complicates the amplifier as well as the load circuit.

Magamp is Durable

Now being used for many applications is the magnetic amplifier. It is extremely rugged and requires little or no maintenance. Isolation of input signals can be obtained by using a number of control fields. Control power requirements can be reduced by using toroidal-type reactors and several stages. The magnetic amplifier also has the disadvantage that push-pull arrangement must be used to obtain reversible dc power.

For voltage regulation the electromechanical amplifier is widely used. It utilizes a reference spring, the force of which is balanced against the magnetic force of a coil excited from the controlled variable. The difference in these forces determines the location of a movable element, which in turn controls the magnitude of a resistor in a generator field. It is a simple self-contained regulator.

SIGNAL SOURCES: A variety of signal sources is used, depending on the controlled quantity. Tachometers, frequency bridges, poten-

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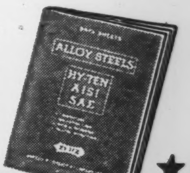

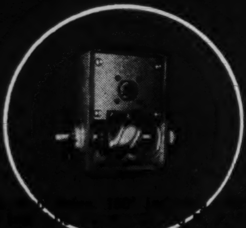

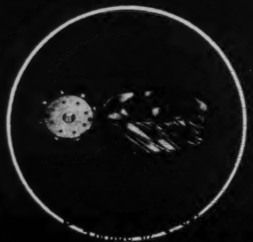

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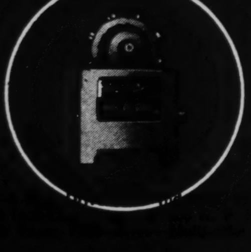

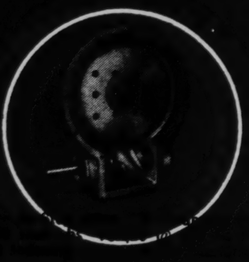

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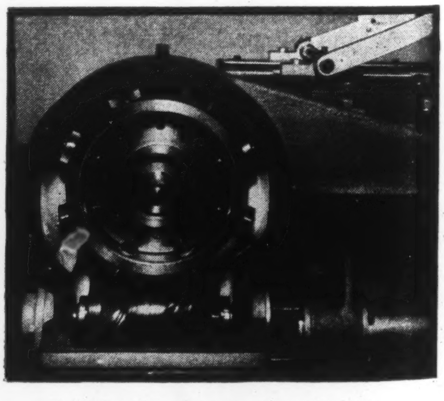

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tiometers, phototubes, and variable reactors are among the more common devices. The use of tachometers and potentiometers has been illustrated in *Figs.* 2 and 3. It is important that the outputs of such devices are linear, temperature variations are small, and that extraneous signals are not picked up.

THE CONTROLLED SYSTEM: The controlled system consists not only of ac and dc motors and generators, but also mill stands, reels, pumps, and other driven elements. Such components are more or less of standard design or are designed to perform a particular function in the processing of a material or the manufacture of a product. However, design modifications in this equipment may be necessary if the results of the system analysis warrant such changes. For example, if the inherent load-voltage characteristic of a dc generator or the low-speed characteristic of a dc motor has a positive slope, a satisfactory feedback control system incorporating such machines is difficult to design. When controlling the position of a strip of material, some processing machine plus a portion of the strip material is included in the feedback control loop. Errors and time delays can be introduced by these inclusions, which cannot be compensated for by other components, and a satisfactory system cannot be designed unless modifications are made.

Application Considerations: With an understanding of the basic principles of feedback control and some knowledge of the required component characteristics, the basic step-by-step requisites for the design and application of such systems which become apparent are:

1. Understanding of the process or manufacturing procedure to be controlled. This involves sequence of operations, accuracy requirements, types of disturbances, smoothness of operation, speed of response, and duty cycle.
2. Knowledge of the characteristics of the components to be controlled. These include load characteristics, inertias, material strengths, and spring constants.
3. Information on conditions affecting operation, such as operating

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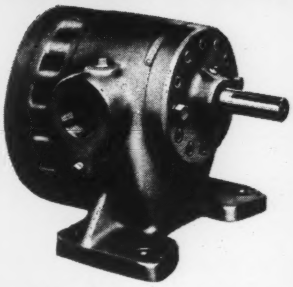

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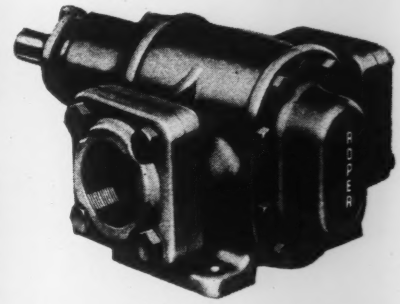

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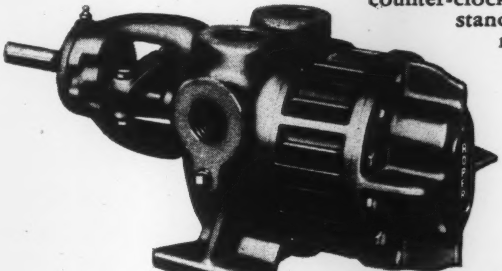

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5. Are they compact . . . do they transmit large horsepower in limited space?	☐	☐
6. Are they sturdy and reliable . . . do not fail suddenly . . . will take abuse in emergencies?	☐	☐
7. Can they be lubricated for long life . . . are not affected by oil or grease?	☐	☐
8. Are they not affected by static electricity . . . free from fire hazard caused by overheating?	☐	☐
9. Are they the quietest medium obtainable in operation . . . free from vibration?	☐	☐
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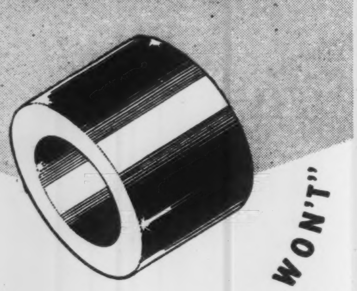

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From an article entitled "Industrial Applications of Feedback Control Systems" appearing in the November 1952 issue of the Westinghouse Engineer.

Improving Bearing Calculations

By R. J. S. Pigott
Director
Engineering Div.
Gulf Research and Development Co.
Pittsburgh, Pa.

LUBRICATION of any bearing involves two distinct considerations: (1) Mechanical suitability of the design, and (2) chemical and physical suitability of the lubricant. The first problem is in the hands of the designer and comprises such factors as:

1. Unit load.
2. Surface rubbing speed.
3. Clearance.
4. Ambient temperature, or heat conduction to and from bearing.
5. Accommodation to thermal and load distortion.
6. Oil flow, both for lubrication and for cooling.

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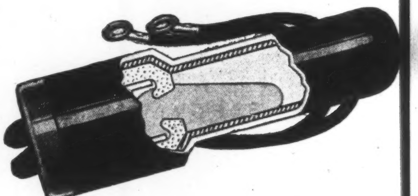

Durakool pressurized all-steel **mercury tilt switches** have more than made good on what may have seemed like extravagant claims a few years ago. The list of Durakool successes grows each year. Seven sizes, 1 to 65 amperes. 3 to 4 weeks delivery. Your production schedule is met.

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HIGH
TEMPERATURES

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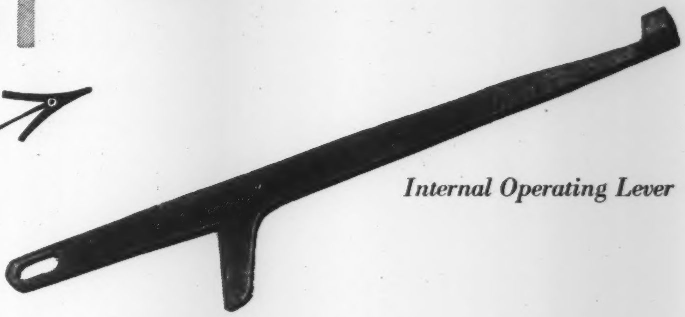
DURAKOOL, INC., Elkhart, Indiana

Durakool
ALL-STEEL MERCURY SWITCHES

These Intricate Parts are PRECISION-CAST

ECONOMICALLY TO CLOSE DIMENSIONS

Housing for Rod Feeder


Internal Operating Lever

These two parts—vital to a starting-rod feeder for a hand-scarfing blowpipe—are produced in quantity by HAYNES precision-investment casting. Both parts are too intricate in shape for accurate production by conventional casting methods. And since they are made from stainless steel, the cost of machining the parts in quantity would be prohibitive.

HAYNES precision casting is an ideal method for mass-producing parts that must be made from an alloy difficult to fabricate into intricate shapes by ordinary methods. Sound, smooth castings are produced to such close dimensional standards that the need for finishing operations is minimized. For more information on the types of parts best suited to this process, and for tips on designing parts to be cast by this method, write for the booklet, "Investment Castings."

The efficiency of the starting-rod feeder on this hand-scarfing blowpipe is partly due to the use of HAYNES investment castings for the critical parts of the assembly.

HAYNES alloys
TRADE-MARK

"Haynes" is a trade-mark of Union Carbide and Carbon Corporation.

Haynes Stellite Company
A Division of
Union Carbide and Carbon Corporation
UCC
General Offices and Works, Kokomo, Indiana
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Chicago — Cleveland — Detroit — Houston
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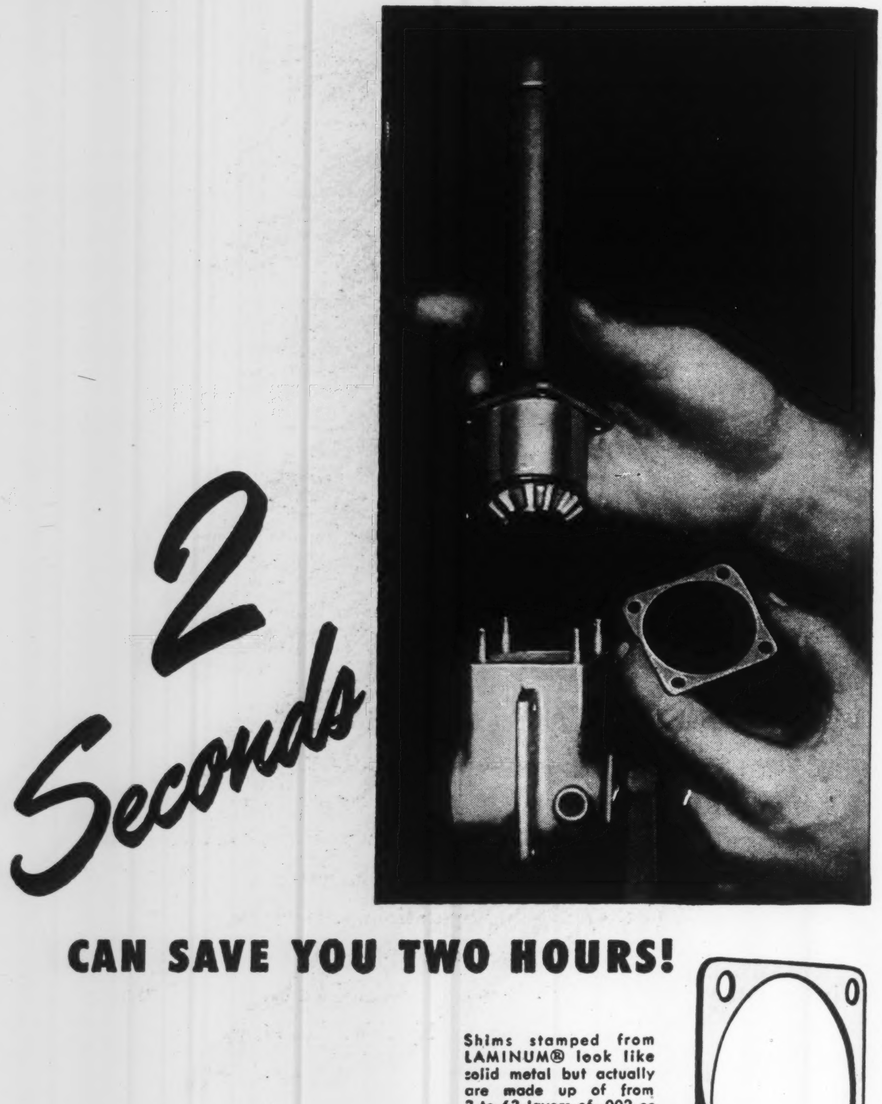

CAN SAVE YOU TWO HOURS!

Shims stamped from LAMINUM® look like solid metal but actually are made up of from 3 to 63 layers of .002 or .003 inch brass or steel.

Adjusting bevel gear mesh with a laminated shim is a matter of two seconds to remove a lamination!

The shim in this case is made of LAMINUM®, our exclusive material. It is a "solid" unit built up of 16 layers of .002 brass. It peels quickly and easily. Each shim removed adjusts the bevel gear position by two thousandths.

You save time by easier machining tolerances on the housing; ***you save time*** by eliminating pesky assembly machining; ***you save*** by not tying up a machine intermittently. IT'S EASIER!

SEND FOR LITERATURE

LAMINATED SHIM COMPANY, INC.

SHIM HEADQUARTERS SINCE 1913

Check Our Stampings Division For Your Stamped Parts Requirements

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curate calculated design and there is little excuse for unexpected failure of bearings.

In addition to adequate design of bearings to carry load and to flow enough lubricant to carry off heat, the whole lubrication system, from the oil sump out, is not only susceptible of accurate design but must be so designed. No bearing manufacturer can safely guarantee performance of his product unless he is assured of the pressure and quantity of oil to the bearings. The pressure and quantity as usually measured at the oil pump are no safe indication of the pressure and flow at each lubrication point. Moreover, in the internal combustion group, both reciprocating and turbine, a large part of the lubricating oil duty is cooling and not lubrication. Since viscosity of oil varies very rapidly with temperature (third to fourth power), control of flow for cooling is highly important since viscosity and consequently load carrying capacity may drop to one-half the normal value if bearing oil flow goes down 20 per cent.

Lubricating System Calculation: Since 1936 work has been directed toward the calculation of lubricating of lubricating systems as complete hydraulic networks. We found that the usual simple assumptions made in laying out the complex series-parallel operation in, say, an automotive engine, were not in accord with the way the system actually operated. Failures were the result.

Experimental tests on actual engines checked calculations very satisfactorily, showing that complete lubricating systems can be calculated about as easily as connecting rod design or loads. To illustrate, in one case investigated the six-throw crankshaft in question was supposed to supply 0.50 gpm. per rod bearing. By calculation, supported by test, it actually supplied 0.035 gpm. to two center bearings, 0.060 to the others; considerable operating failure had occurred on the road. A simple change of grooving cured this case.

The method employed by this laboratory consists of calculating

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Hess-Bright Pillow Blocks

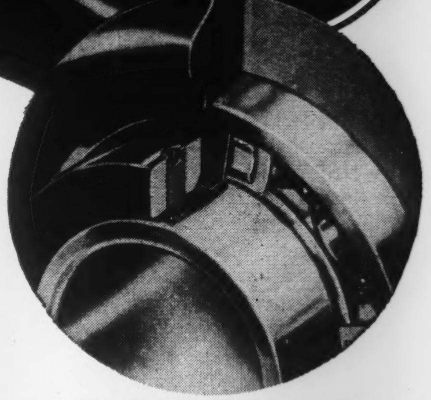
NEW from SKF

the HESS-BRIGHT "SY" UNIT PILLOW BLOCK

A new Unit Pillow Block, designed by SKF *to meet tomorrow's needs of modern industry.*

Here are the design features:

- SKF Red Seal, made of DuPont Fairprene, retains lubricant. Wiping action of the seal against the inner ring is practically frictionless.
- Rotating flingers exclude dirt.
- Set screws for ease of installation.
- Spherical outer ring compensates for initial misalignment.
- Alemite fitting for re-lubrication.
- Interchangeability with existing installations made possible by bolt hole spacing and center height features.
- Shaft diameters 1$\frac{3}{16}$" to 2$\frac{15}{16}$".



Detailed illustration of rotating flinger and RED SEAL—the extremely light tension contact seal.

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BALL AND ROLLER BEARINGS

IN EVERY INDUSTRY, SKF Puts The Right Bearing In The Right Place

From now on, the name to remember in Unit Pillow Blocks is HESS-BRIGHT "SY"—manufactured in our plants, to the same high quality standards as all SKF products. Ask your SKF Distributor to show you the HESS-BRIGHT "SY"; or write SKF direct for complete information on this *newest* Unit Pillow Block.

SKF INDUSTRIES, INC., Phila. 32, Pa.—*manufacturers of* SKF *and* HESS-BRIGHT *bearings.*

7322-A

the eccentricity ratio, using S. J. Needs' load capacity and leakage factors. For this calculation the following data are required:

1. Load diagram (design).
2. Bearing dimensions and clearance.
3. Assumed crankcase temperature.
4. Viscosity and temperature coefficient of viscosity of oil.

In addition, from the eccentricity ratio, the work done (with consequent temperature rise) and the flows must be determined for a range of pressures at the bearing inlet. The pressures at the inlet must allow for centrifugal forces in the case of crankpin bearings.

Given the pressure-flow data for each bearing, the conduit network supplying these bearings can be calculated for a range of flows. Since the pressures at the inlets of the bearings are affected by the preceding friction losses in the conduit network, there is no unique solution and graphic methods are convenient. It will be found that the flow in most oiling systems is in the viscous region, with the possible exception of the main gallery line and certain grooved passages in bearings where turbulent flow is produced by mechanical agitation. In practically all cases the bearings are of sufficiently high resistance relative to the conduit network to control the flow distribution.

The inertia forces of the oil column in the connecting rod must be taken into account as affecting the connecting-rod big-end bearing and the wrist pin when using drilled rods to supply the wrist pin. We have found that several commercial designs may intermittently or continuously have foam in the rods instead of a solid column of oil, thus endangering bearings at both ends. This condition is due solely to neglecting to calculate the conditions in the rod as affected by the inertia forces.

The whole calculation is perhaps tedious and very lengthy but not particularly abstruse. The effect of bearing grooving on oil flow is unfortunately not well supported by adequate test information. It is

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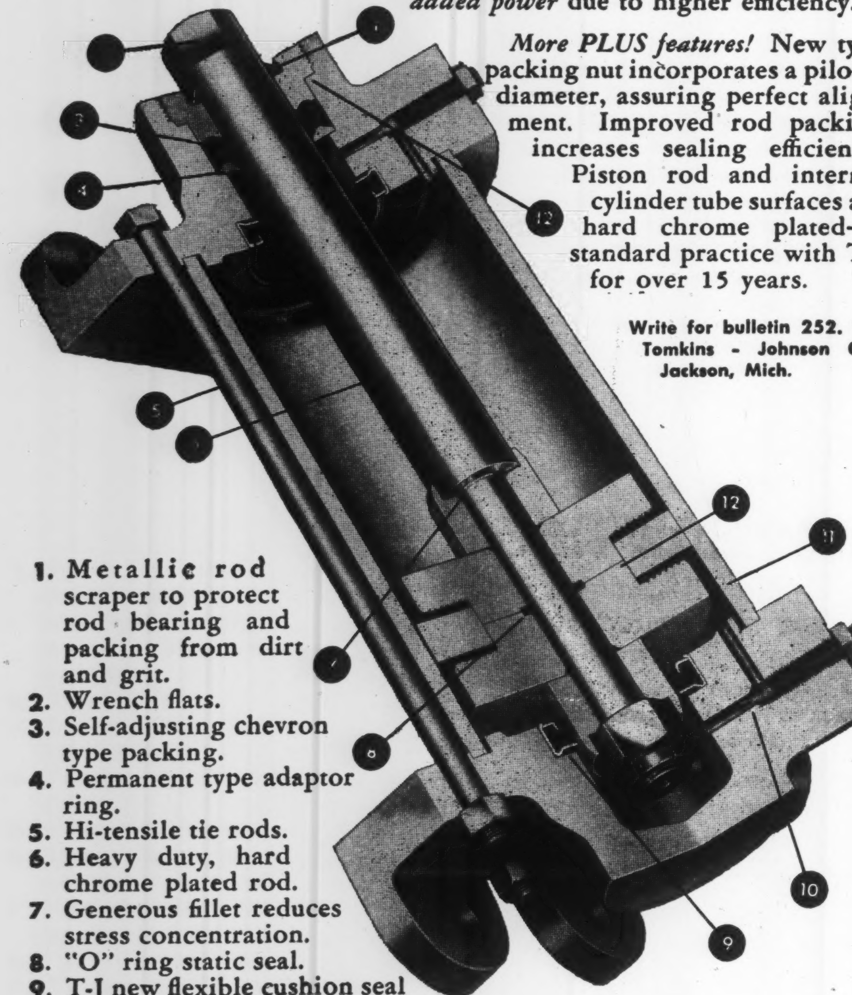
T-J AIR CYLINDER
Designed with revolutionary application of
Super-Cushion

It's *sealed with pressure*—a revolutionary T-J application of flexible sealing that insures positive cushion action combined with automatic valving action for fast return stroke . . . eliminates binding and sticking . . . operates with *low friction, minimum wear,* and *added power* due to higher efficiency.

More PLUS features! New type packing nut incorporates a piloted diameter, assuring perfect alignment. Improved rod packing increases sealing efficiency. Piston rod and internal cylinder tube surfaces are hard chrome plated—a standard practice with T-J for over 15 years.

Write for bulletin 252. The Tomkins - Johnson Co., Jackson, Mich.



1. Metallic rod scraper to protect rod bearing and packing from dirt and grit.
2. Wrench flats.
3. Self-adjusting chevron type packing.
4. Permanent type adaptor ring.
5. Hi-tensile tie rods.
6. Heavy duty, hard chrome plated rod.
7. Generous fillet reduces stress concentration.
8. "O" ring static seal.
9. T-J new flexible cushion seal insures positive cushion with automatic valve action for fast return stroke. (Patent applied for)
10. Fine cushion adjustment.
11. Heavy wall precision honed hard chrome plate.
12. Controlled packing compression with metal to metal contact.

36 YEARS' EXPERIENCE T-J
TOMKINS-JOHNSON
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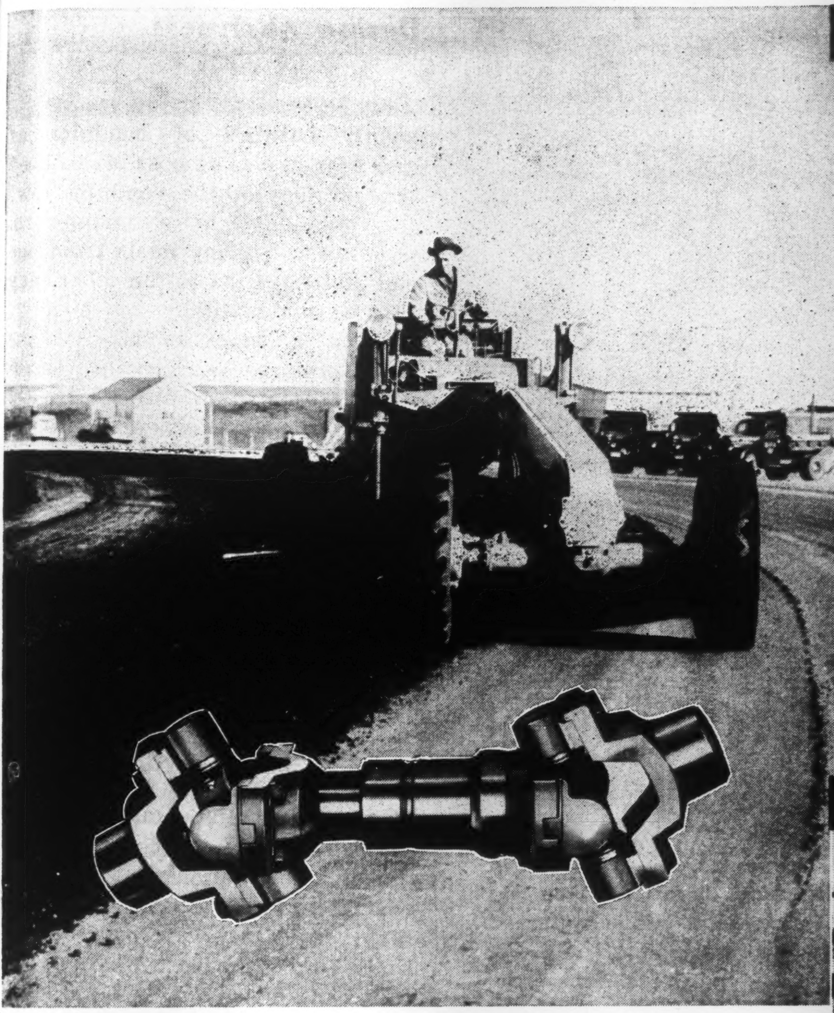
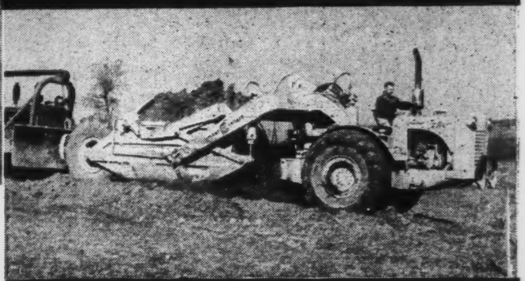
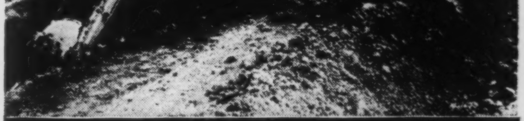


FOR EARTH MOVERS



FOR TRENCH DIGGERS



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MECHANICS JOINTS

Are Used on the TOUGH JOBS

Designers with JOINT problems have learned to rely on MECHANICS. Where joints must run all day at constant angles up to 45°—where there are severe shock loads—where wide angles and long slip are common—and where dirt and/or moisture are continually present — MECHANICS Roller Bearing UNIVERSAL JOINTS are the accepted solution. Lubrication is so tightly sealed in that dirt and moisture cannot enter. If you have a "tough" joint problem, make use of MECHANICS engineers' wide experience.

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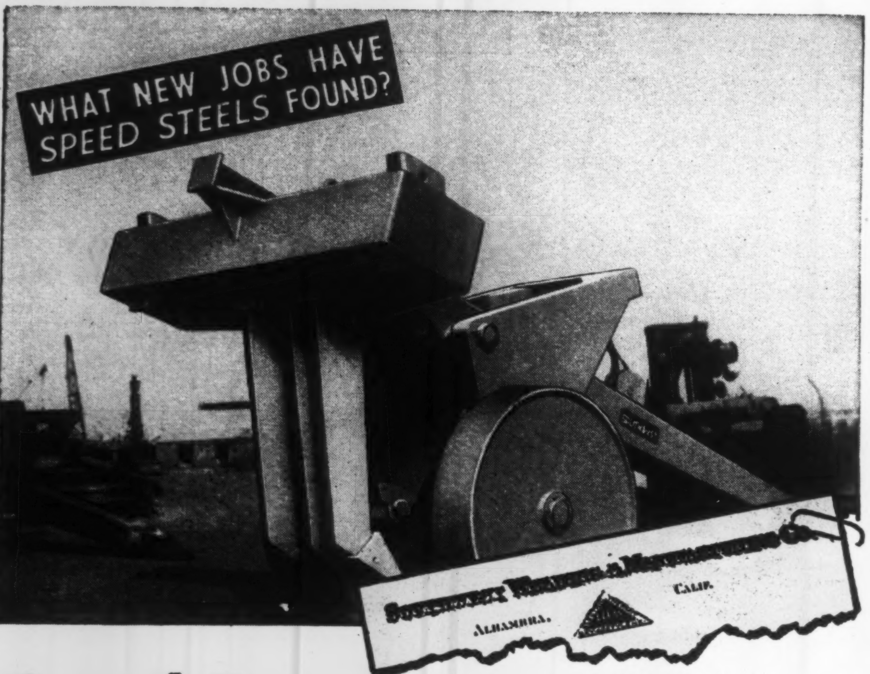
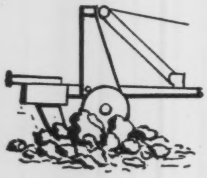

WHAT NEW JOBS HAVE SPEED STEELS FOUND?
SOUTHWEST WELDING & MANUFACTURING CO.
ALHAMBRA, CALIF.

Speed Treat Steel Gives Powerful Brute A Tremendous Bite



The big teeth of this Southwest Cable Ripper have to penetrate rock hard surfaces up to 60" deep and withstand tremendous shock loads. A hard-packed airport runway, for example, snapped off ordinary steel shanks like toothpicks. To give this powerful brute teeth with a real bite Southwest is making them of Speed Treat (x1545) Plate Steel.

A tensile strength of 90-100,000 PSI and Brinell hardness of 156-196 imparts exceptional ruggedness and wearability to these vital components. Speed Treat is a versatile steel, too. Its unusual machinability plus its high physical properties, imparted by its .45% carbon and 1.25% manganese content, have won industry's favor for mechanical rubber molds, flame or induction hardened gears, sprockets, cams, eccentrics, cylinder bearers and countless other items, where machinability, finish, tool life and hardenability are important factors. Chances are you can improve your own product and save money with Speed Treat. Why not talk it over with your Speed Steel Distributor? Literature on request.

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Produced by W. J. Holliday & Co., Inc., Speed Steel Plate Division, Hammond, Indiana. Plants: Hammond and Indianapolis, Indiana

wise, in general, to make the oil supply network of conduits as generous in size as possible to keep friction loss in the conduits low; the possibility of a nonuniform pressure at bearing inlets from one end of the engine to the other may thus be minimized.

From a paper entitled "Some Considerations in Bearing Operation" presented at the ASME Oil and Gas Power Division meeting in Buffalo, N. Y., June 1952.

Punched-Card Problem Solutions

By Rudolph Habermann Jr.
and Frank J. Maginniss

Analytical Division
General Electric Co.
Schenectady, N. Y.

CALCULATING machines are so essential to the modern engineer or scientist that fabulous computers have been built to serve him. But there are many situations where the cost of these so-called mathematical robots cannot be justified, even though they are badly needed. In other words, there is a wide gap between the portable or desk-type calculator and the computer costing anywhere from a half million to a million dollars.

Punched-card equipment can help fill this gap. There are many types of such machines of which the most important is the calculator. Such a machine can recognize the holes in standard punched cards as numbers. It can perform the elementary arithmetic operations of addition, subtraction, multiplication, and division on these numbers, and record the answers in the form of additional holes which it punches in the cards. Such a machine also has some memory; that is, it can place in storage the values of the numbers it reads from the punched cards until it has performed the necessary calculation on those numbers. Furthermore, the calculator has at least some capacity for sequential calculation for it will allow the machine to do a sequence of opera-

NEW PACKAGE SEAL—small shafts

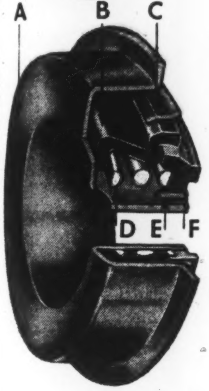
JOHN CRANE

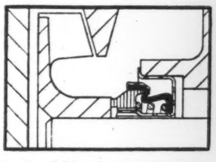
THE Pressed-In SEAL

POINT FOR POINT

1. Is a low cost unit.
2. Simplifies machine design.
3. Saves on manufacturing costs.
4. Provides a positive drive.
5. Eliminates all torque strains on flexing member.
6. Compensates for washer wear.
7. Has plenty of axial and radial movement.
8. Protects component parts.
9. Assures a liquid-tight job.
10. Improves performance.
11. Permits perfect lubrication.
12. Has lapped faces.
13. Has plenty of take-up.
14. Uses only selected rubber stocks.
15. Minimizes cavitation around pump shafts.
16. Permits cooling of rubbing faces.
17. Is a production line item.
18. Is individually tested.

LOW COST





A. Seal Retainer.
B. Synthetic Rubber Bellows.
C. Metal Band.
D. Spring.
E. Holding Dents.
F. Precision-Lapped Sealing Washer.

STATIONARY SEALING HEAD TYPE 11-A

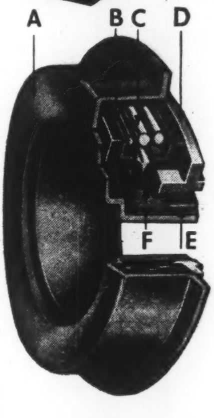
This pressed-in packaged sealing unit is designed to protect the spiral steel spring inside of the synthetic rubber bellows against corrosion.

The spring clamps the flange of the bellows tight against the bottom of retainer and the metal ferrule squeezes the top portion of the bellows against the "Teeplelite" washer.

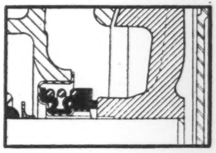
This liquid-tight seal is especially recommended for small shafts on *hot or cold water, oil, gasoline, kerosene, soapy water.*

Use this seal on: *Low Pressures* 35 PSI
Low Temperatures −65°F. to 220°F.

LOW COST



STATIONARY SEALING HEAD TYPE 6-A



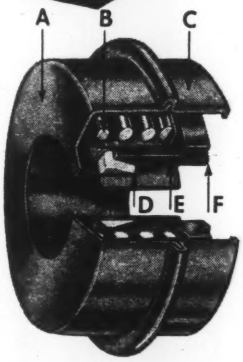
A. Seal Retainer.
B. Metal Ferrules.
C. Spring.
D. Precision-Lapped Sealing Washer.
E. Holding Dents.
F. Synthetic Rubber Bellows.

This pressed-in packaged sealing unit is designed with a spiral steel cadmium plated spring (stainless or bronze optional) assembled between two metal ferrules which clamp the flanges of the synthetic rubber bellows tightly against the retainer shell and the "Teeplelite" washer.

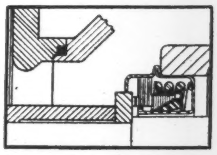
This liquid-tight seal is especially recommended for small shafts on *hot or cold water, oil, gasoline, kerosene, soapy water.*

Use this seal on: *Medium Pressures* 75 PSI
Low Temperatures −65°F. to 220°F.

LOW COST



STATIONARY SEALING HEAD TYPE 9-A



A. Seal Retainer.
B. Spring.
C. Sleeve.
D. Wedge of Teflon.
E. Sealing Washer.
F. Precision-Lapped Face.

This pressed-in packaged sealing unit is designed to use a wedge sealing ring of Teflon*. This wedge shaped sealing ring closely fits the inner sleeve of the retainer and makes a liquid-tight contact with cone surface of carbon washer.

The result is a liquid-tight seal which is especially recommended for *hot oil, and all chemical liquids or gases, hot or cold.*

Use this seal on: *High Pressures* 200 PSI
High Temperatures 350°F. *Low Temperatures* −100°F.

Crane Packing Company, 1825 W. Cuyler Ave., Chicago 13, Ill.

1. Compact new packaged units.

2. Stationary sealing head, pressed-in type.

3. $\frac{1}{32}$" clearance around shaft, ¼, ⅜, ½, 1" diameter.

4. No vibration.

5. Easy to install, easy to replace.

6. Liquid-tight.

7. Minimum friction, cool running.

8. Minimum wear, rubbing.

9. Great flexibility.

10. Inspected parts.

11. Tested.

12. Closer bearings.

13. Shorter shafts.

14. No shaft deflection.

15. No run-out.

16. High speed.

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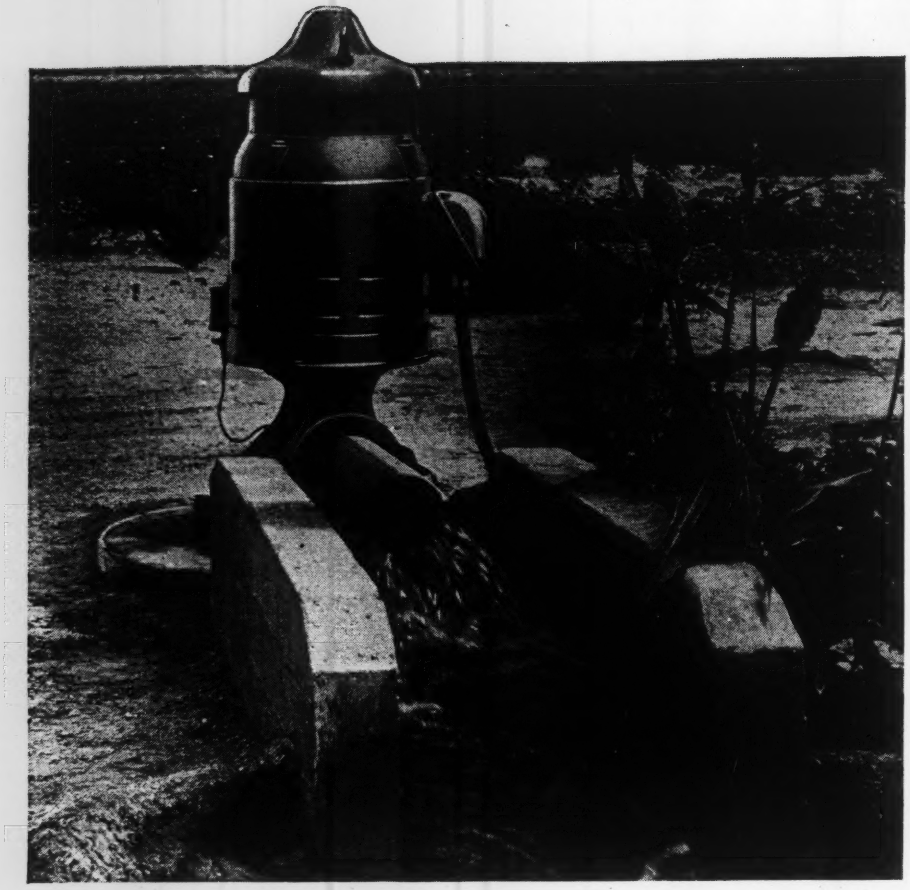
*Du Pont Trade-mark for tetraflouroethylene resin

CRANE PACKING COMPANY



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POWER TO SPARE

SMITHway Vertical Hollow-shaft Motors have *reserve power* which enables them to carry sustained overloads without injurious overheating. This is just *one* of the *many* reasons why they're the choice of users in every category—private, corporate and municipal, where water supply must be dependable and delivery must be at lowest cost per gallon. For complete information, see nearest office or write for latest bulletins.

OUTSTANDING FEATURES: *Rugged cast iron frames and end bells. Weather proof, protected construction. Precision machined throughout. Moisture resistant insulation. Pressure cast, dynamically-balanced rotors. Dual-balanced ventilation. Sealed bearing enclosures. Easy to service. Many other features. Wide range of ratings from 1 to 500 H.P. SMITHway Motors also available in Solid Shaft Design over the same range.*

SMITHway 78th ANNIVERSARY 1874 - 1952

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ELECTRIC MOTORS

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tions on the numbers found on the cards as they pass through the calculators.

For example, we might want to find the value of y corresponding to a large number of values of x in the polynomial

$$y = 35x^2 + 17x + 2.7$$

The constant numbers 35, 17, and 2.7 can be entered in the storage of the machine, where they will be available at all times during the calculation. A deck of cards, one card for each of the values of x in which we are interested, can then be fed into the machine. The value of y can now be calculated and punched on each card to go with the corresponding value of x.

How do we tell the machine to evaluate y? The answer lies in the control panel. This is the nerve center of the machine, which causes it to perform the required arithmetic calculations by interconnecting the machine's internal circuits.

One possible sequence of instruction which might be wired into the control panel, thus causing the calculator to do what we want, could be:

1. Read the value of x from the card into storage.
2. Multiply x by 17, and store the product.
3. Add the result of step 2 to the number 2.7, which is in storage, and store the sum $(17x + 2.7)$ for future use.
4. Take the value of x from storage and multiply it by itself, giving x^2.
5. Multiply the x^2 from step 4 by the number 35, which is found in storage, giving $35x^2$.
6. Add the results of steps 3 and 5, giving the result $35x^2 + 17x + 2.7$.
7. Punch this result on the card and go on to the next card with its new value of x.

This process could be repeated over and over again for as many values of x as we care about and with no further attention to the machine on the part of the operator.

One type of calculator in common use operates at the rate of 100 cards per minute. Thus, if we should wish to evaluate y for 1000 different values of x in the foregoing equation, the actual calculating time would be only 10 minutes. To this, of course, must be added the time required to plan the work, make up the control panel, and punch original data into the cards. This is a very simple example, but its extension to a more complicated calculation is obvious.

As examples of the kinds of job which can be done with them, a few problems have been chosen from the many which have been undertaken. Not all are necessarily typical, but each illustrates a different computing technique.

Field Problems: Numerous kinds of field problems confront the engineer. Knowledge of the distribution of magnetic flux density in an electromagnetic device is necessary to determine the magnetic forces acting on various parts of the device. The distribution of stress in an elastic member is of vital importance in determining the safety of a structural member. Many other field quantities, such as velocity and pressure in a fluid field or the potential in an electrostatic field, are quantities the engineer would like to have some easy way of determining.

The characteristic common to all field problems is the fact that they give rise to partial differential equations. Now, in all but the very simplest cases it is impossible to obtain solutions of such equations analytically. One method for the approximate solution of such equations is to replace them by a system of finite difference equations. For example, instead of trying to calculate the smooth continuous distribution of flux density in a magnetic field, we calculate its values at a finite number of points in the field, separated from each other by definite space intervals. This may result in a very large number of simple algebraic equations, depending on the size of space increment, which must be satisfied simultaneously. If the number of them is not too great, they may be handled as a

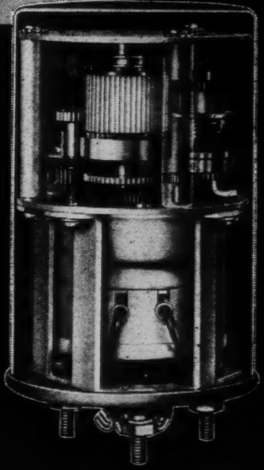
Designed to meet U. S. Government requirements*

Cramer

HERMETICALLY SEALED timing relays

type HRR CIRCUIT RECLOSING RELAY

Compact . . . sturdily constructed . . . reliable in operation . . . the Cramer Type HRR Circuit Reclosing Relay is designed to perform many functions including: (1) Use as protective device for electronic equipment which automatically restores the equipment to service following a minor fault, yet protects the equipment against damage should the fault persist; (2) As a supervisory control for the automatic starting of engine, the Type HRR Relay applies specific cranking periods at spaced intervals and locks out the control should the engine fail to start within a prescribed time.



* These instruments have been successfully tested under the following conditions:

Temperature: -65 - 185 F.

Acceleration: 75 G's

Vibration: 5 to 60 cps. at 1 32″ amplitude

Salt Spray: 200 hours

Inclination: Any position

Humidity: 100% plus condensation

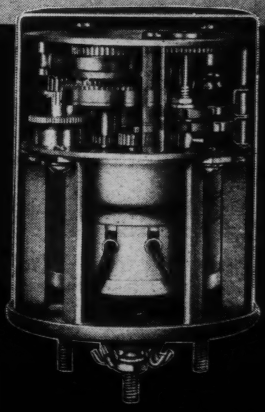
Altitude: 50,000 ft

Miscellaneous: Fungus, dust and sand

type HTI MINIATURE TIME DELAY RELAY

Constructed from standard Cramer time-tested components in a compact form, the Type HTI Miniature Time Delay Relay is primarily designed for use in electronic circuits . . . or in any application where it is desired to provide a fixed time delay between the closing of a control circuit and the subsequent closing or opening of a secondary circuit.

Type HTI Relays are available in maximum time ranges from 30 seconds to 30 minutes.



For complete information, write for Bulletin No. 4000A

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Builders of dependable timing devices for more than 25 years.

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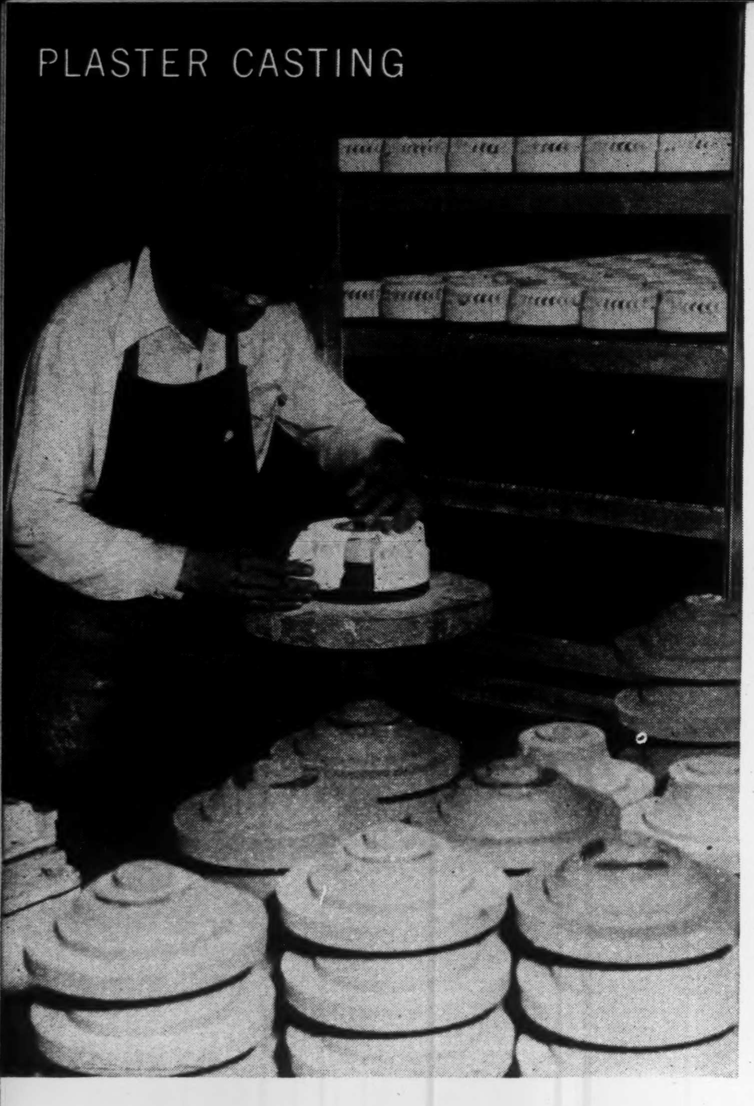

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SAND CASTING

ALCOA MAKES LIGHT METAL CASTINGS BY ALL FOUR PROCESSES

When you discuss your casting job with an Alcoa sales engineer, you can be sure that he will recommend the process that best fits your needs. If your part should be die cast, two modern die casting plants and 30 years' die casting experience back his recommendations. He can also suggest sand casting, for Alcoa has five sand foundries and 41 years' experience in the casting business. Permanent mold castings? Four of our foundries make permanent mold castings. One in Detroit specializes in plaster casting. Obviously, Alcoa sales engineers have no axe to grind for any one process.

The same applies to choice of light metals. Alcoa's casting facilities are equipped to handle both aluminum and magnesium. Alcoa casting specialists are old hands at working with light metals. Alcoa engineers are completely unbiased in their approach to any question you might put to them. For these reasons, Alcoa sales engineers are quick to point out the advantages of both aluminum and magnesium for your application.

Your first step toward using these extensive facilities is to call your local Alcoa sales office—listed under "Aluminum" in the classified phone book. Or write:

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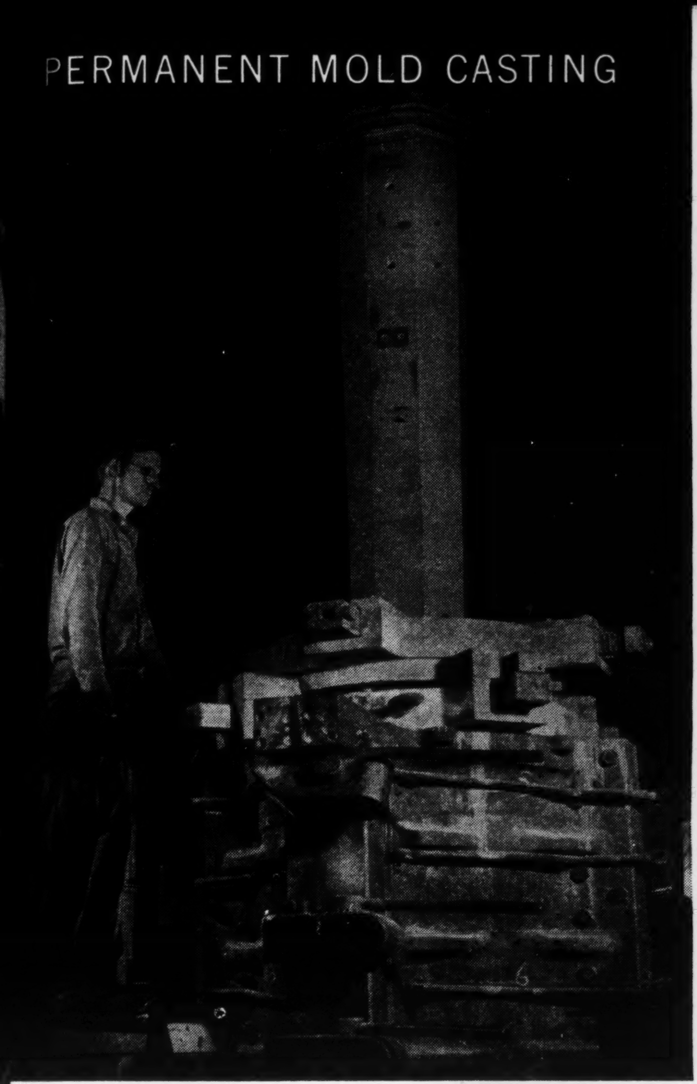
PERMANENT MOLD CASTING

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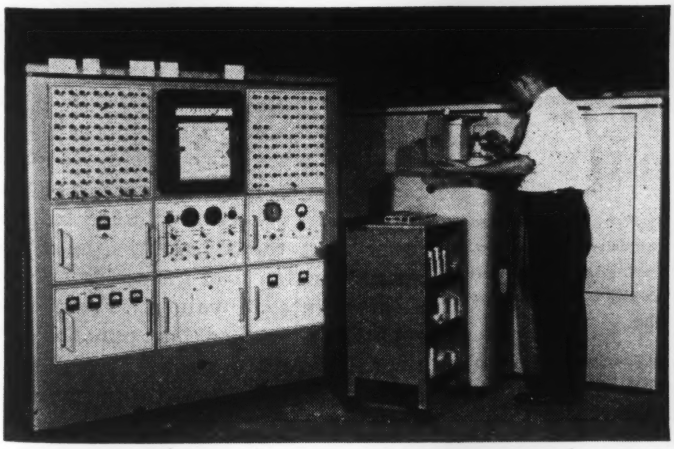
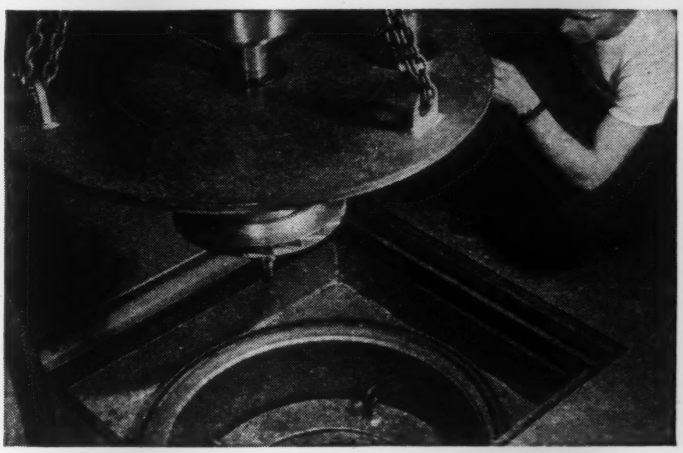

ALLOY CONTROL—Alcoa foundries are equipped with direct reading quantometers, like this. In less than a minute, these instruments provide a complete spectrographic analysis of an alloy being cast.


RESEARCH TEST—In Alcoa's 70,000 rpm whirlpit, rotating parts can be tested to destruction. Provision is also made for brittle lacquer and strain gage investigation while the rotating part is under stress.

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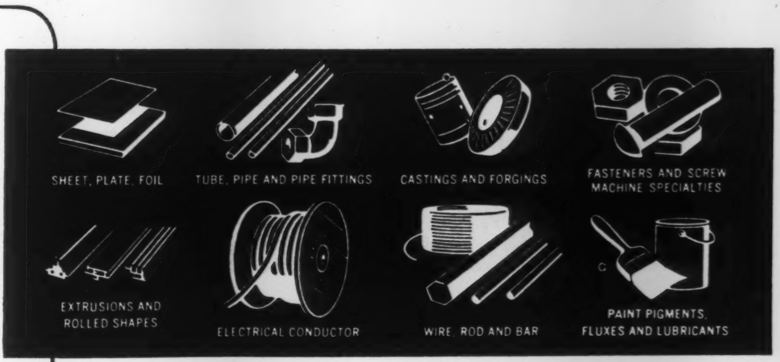
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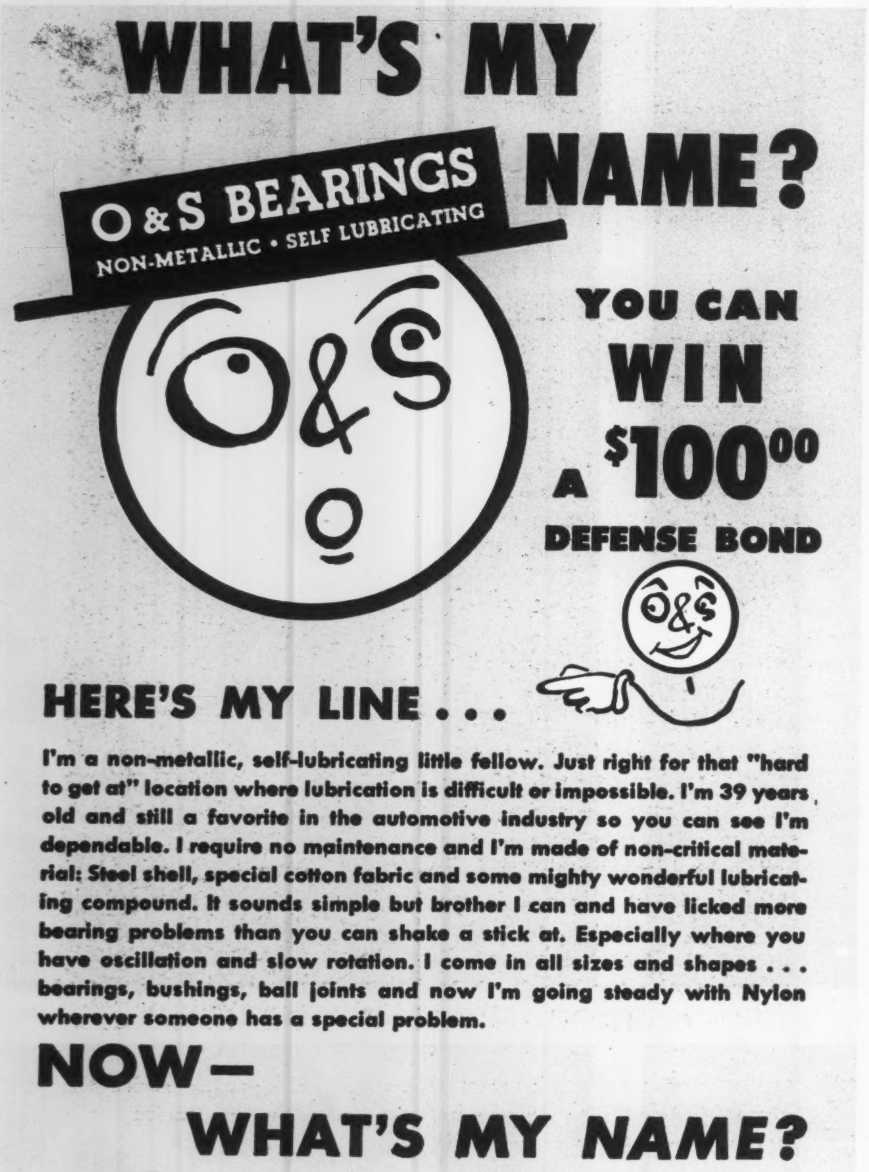
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Win a $100.00 Defense Bond—give me a name! Submit any number of names. One name will be selected. In case of duplication—the earliest postmarked will win. All entries must be postmarked before contest closes Midnight, December 31, 1952.

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set of linear simultaneous equations and solved once for all.

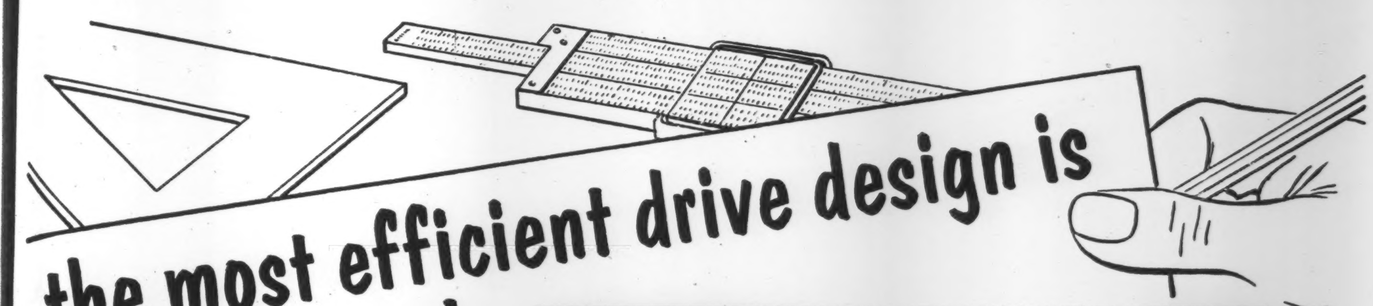
When, however, the number of these equations is large, we may have to resort to an iterative procedure. This consists of making a guess—presumably an educated one—at the value of the function at each point within the known boundaries of the field, then, for each point in turn determining a new value of the function by substituting the guessed values into the corresponding algebraic equation. In this manner the field can be traversed a number of times, until the values of the function at all interior points settle down and appear to be approaching steady values.

This iterative method of solution was applied to the problem of determining the pressure distribution in the oil in a slider bearing of finite space dimensions, taking into consideration the effect of variable viscosity. After appropriate assumptions had been made, this resulted in a somewhat formidable partial differential equation, expressing the oil pressure everywhere over the surface of the bearing in terms of the x and y co-ordinates of the point on the surface.

As a preliminary to the punched-card set-up for this problem, an analogous dc network was set up to represent the pressure field. Voltage readings at node points in this network corresponded to pressures at these points, thus giving an educated first guess for approximate interior values. From these starting values, a punched-card procedure was set up to carry out the process of improving values at all points.

In such procedures, a number of problems can be handled at the same time. We may, for example, be interested in the effect of minimum clearance, the ratio of maximum to minimum clearance, the type of oil (as shown by the shape of the viscosity curve), or the effect of temperature distribution, which will also determine the viscosity values.

Amplifying Circuits: With the advent of complicated servomech-



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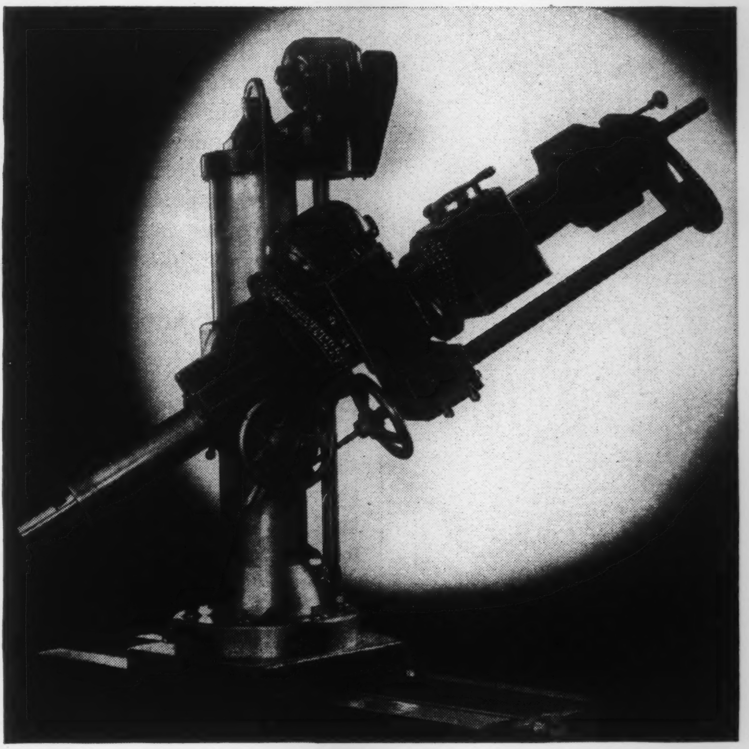

VEELOS V-BELT

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- Outboard bearings are practical because Veelos can be installed without dismantling any part of the machine.
- Correct tension can be maintained on all belts to provide full, vibrationless power delivery.

And remember, Veelos v-belt is made in all standard widths: 00, 0, A, B, C, D and E, double V in 0, A and B. Available in three types: regular, oil-proof and static conducting.

A VEELOS DATA BOOK will gladly be sent you on request and if you have any drive design questions send them along to us, our engineers may be able to help.

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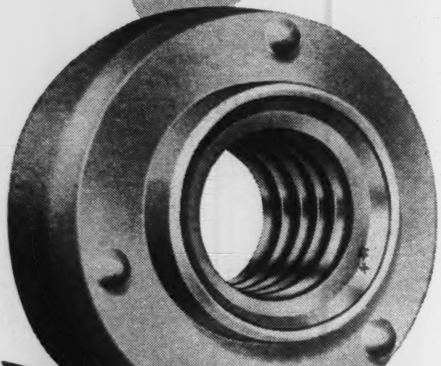

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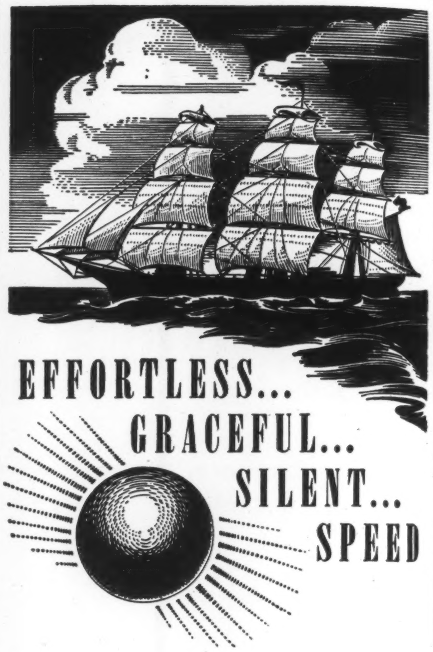
anisms and dynamic control systems, it becomes almost essential to find some rapid means of calculating the performance of an amplifying circuit which can contain many feedback loops and mutual elements. Short-cut hand-calculation methods have been devised for plotting the gain and phase shift of such systems but these are used at the expense of accuracy. Where it becomes necessary to determine with a good deal of accuracy the frequency response of such a system, rigorous mathmatical methods must be applied.

Steady-State Equations

In one example, there are four loops around which the complex steady-state voltage-drop equations can be written. In writing the steady-state equations, we assume that, when a sinusoidal input voltage is applied to the system, the output voltage will also be sinusoidal but changed both in magnitude and in phase from the input. It is these quantities we wish to find—the change in magnitude or gain, and the phase shift of the output with respect to the input. Moreover, since the coefficients of the unknown currents in the mesh equations are dependent on frequency, the gain and phase shift will also vary as the frequency of the input voltage is changed.

For any given frequency, the mesh-current equations are four equations with complex but constant coefficients. These may be reduced to eight equations with constant real coefficients. By solving this set of eight equations, we can calculate the value of both magnitude and phase of the output voltage with respect to the input.

The manual solution of a set of eight simultaneous equations would be nearly as easy as the same calculation done on punched-card equipment, provided only one such set of equations was to be solved. In the given example, however, one solution gives us the gain and phase shift for only one frequency of the input. An average frequency-response curve may require that we try 12 or 15 different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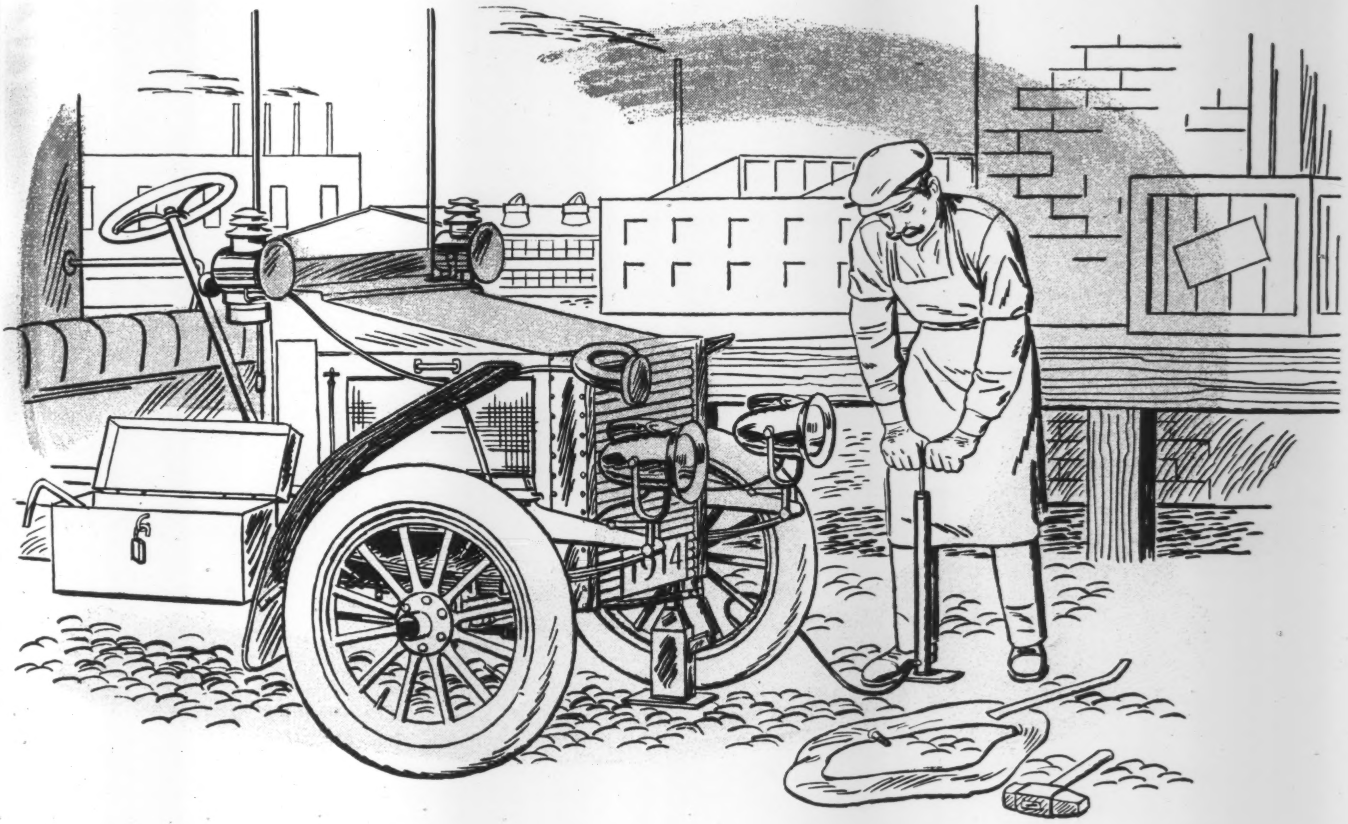

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Emerson-Electric Motors were first used on air compressors in 1899, and the progress of the industry has been matched with improvements in the motor drives.

Emerson-Electric builds dependable, efficient motors for equipment used in industry, in business, on the farm and in the home. There is a complete line of Emerson-Electric standard motors in horsepower ratings from 1/20 to 5, and hermetic motor parts in ratings from 1/8 to 15 horsepower. Your inquiry is invited.

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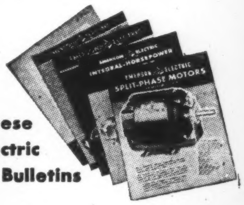

Write for these Emerson-Electric Motor Data Bulletins

Manufacturers requiring motors 1/20 to 5 h.p. can profitably use these reference guides. Specifications, construction and performance data are included for these motors:

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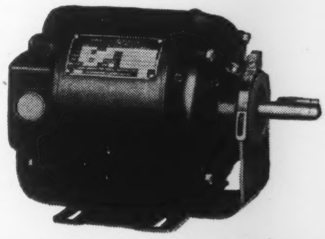
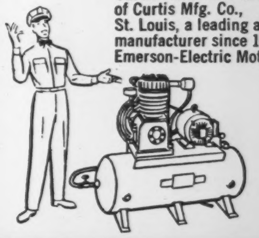
☐ M158-B Split-Phase
☐ M158-C Integral
☐ M158-D Fan-Duty
☐ M158-E Oil-Burner
☐ M158-F Jet Pump
☐ M158-G Blower





Curtis Pneumatic Mach'y Div. of Curtis Mfg. Co., St. Louis, a leading air compressor manufacturer since 1896, is a user of Emerson-Electric Motors.

EMERSON ELECTRIC
MOTORS • FANS APPLIANCES

LEADERS IN THE MOTOR AND FAN INDUSTRY SINCE 1890 values of frequency. Moreover, it will probably be interesting to find out how the frequency-response curve is affected by variation of some of the circuit parameters. For each new circuit investigated, the multiplicity of sets of equations increases rapidly—we may find ourselves with 150 to 200 sets.

And that is where the punched-card calculator really pays off. Carrying along a number of sets in parallel greatly reduces the unit time of solution. All of this illustrates the fact that punched-card machine computation is most effective when a large number of repetitive calculations must be performed.

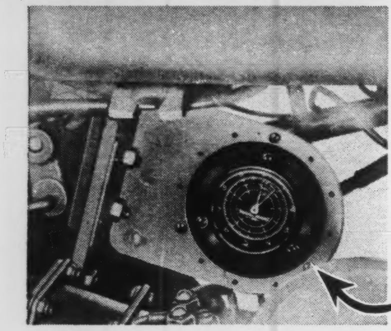
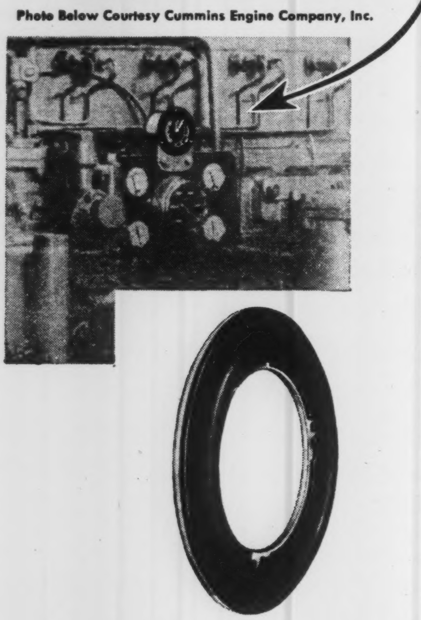
From an article entitled "Let Punched Cards Solve That Problem" appearing in the General Electric Review for May 1952.

Nondestructive Analysis for Thin-Wall Shells

By J. C. New
Mechanical Engineer
Naval Ordnance Laboratory
Silver Spring, Md.

THIN shells occupy a significant and often critical place in many modern engineering structures. These structures are, in general, loaded by an external pressure. Their failure is most often characterized by a sudden and dramatic collapse. Thus, intelligent and precise design must be executed for a safe and efficient structure. Mathematical theory and past experience must be supplemented in new and unusual design by experimental results.

The differential-pressure test is an original, nondestructive, experimental technique for determining incipient buckling pressures of thin shells subjected to external pressure. Extensions of the basic test permit study of many buckling parameters as well as other mechanical factors in thin-shell design and evaluation. The salient feature of the technique is the filling of the internal volume of the shell with a compressible fluid, such as water, to control the magnitude and rate of shell deforma-

LORD METER MOUNTS
PROTECT INSTRUMENTS
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Photos Courtesy The Massey-Harris Company.

Photo Below Courtesy Cummins Engine Company, Inc.

The Sure Way to "Design out" Vibration and Shock Damage.

Lord Meter Mountings are paying dividends to manufacturers and users of heavy duty industrial and farm tractors, lift trucks, stationary engines and many other industrial machines where shock and vibration are encountered.

The Lord Meter Mount assures the accurate performance designed into Hobbs Engine-Hour Meters when they are subjected to excessive vibration on farm tractors and stationary diesel engines. These meters are protected from the damaging effects of vibration and shock by the unique method of combining shear and rolling action of the rubber to absorb destructive forces. The outer ring is mounted to the panel and the inner ring holds the meter thus giving protection in multi-planes. The rubber between these rings does the work. We will be pleased to have the opportunity to help you in the application of Lord Meter Mountings.

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Santa Claus STANDARDIZES WITH OHIO

Howdy Doody copyrighted by Kagran Corporation, New York

Illustration shows the VOT reducer used in animating the above Christmas display, and its location in each figure. The ratios are 100 to 1, and 60 to 1, with the BHU reducer having a ratio of 48 to 1.

About this time of year, Ohio Gear's little VOT and BHU reducers go to work for Santa Claus, grinding out smiles and giggles for kiddies at Christmas time, in store windows all over the country.

Old King Cole Displays, Inc., of Louisville, Ohio, manufacturers of animated displays, is putting a lot of faith in Ohio Gear and paying a great tribute to a reducer to keep their product operating a thousand miles from home. Ohio Gear, in turn, has the great responsibility of protecting the name and business of Old King Cole Displays, Inc.

As many as 25 to 50 reducers are used in a single Old King Cole display, such as brass bands and larger Christmas displays, and it is with great satisfaction that Old King Cole Displays know their product is insured with Ohio Gear reducers, for continuous, trouble-free performance.

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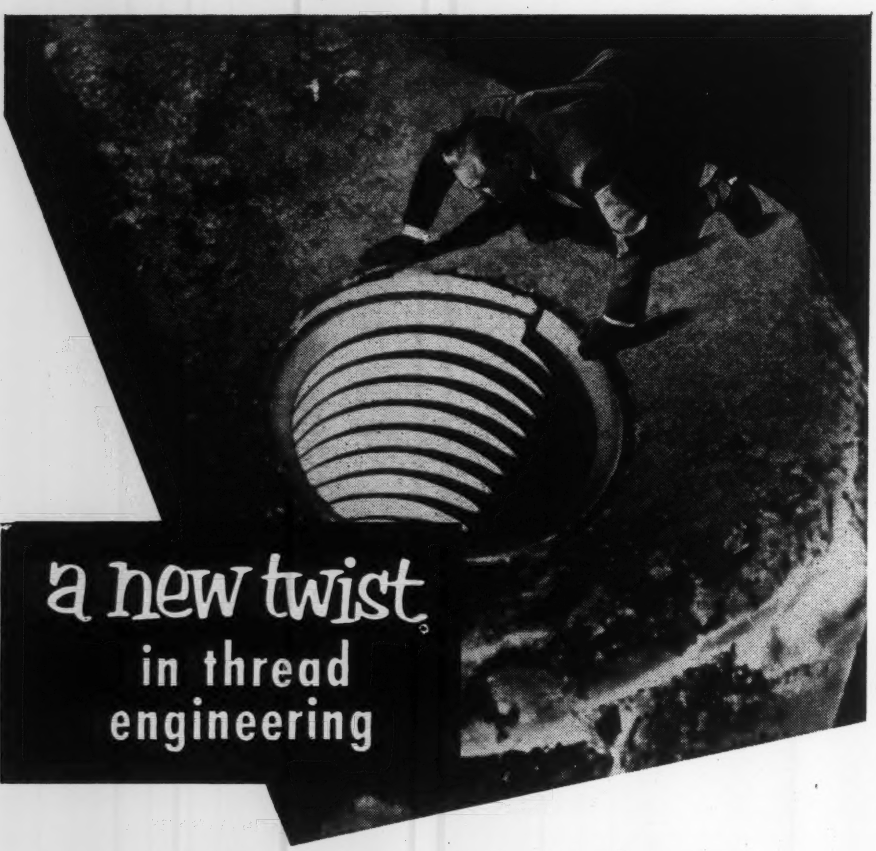

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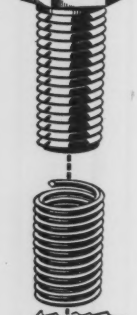

This alone will be a decided advantage for your products in the competitive market. But there are still further basic design improvements and savings possible with ***Heli-Coil*** Inserts.

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tion. The incipient buckling pressure is detected by noting the point at which the difference in internal and external pressure becomes constant.

Theoretical Considerations: The buckling or collapse of a thin shell is a manifestation of the lack of equilibrium between the external applied pressure and the stress developed in the shell wall. If such a stress is substantially below the elastic limit, we characterize such a failure as being due to elastic instability. If the stress at the time buckling is in the inelastic range of the material, then, in popular terms, a failure by yielding is noted. In either case, a state of unstable equilibrium exists causing an uncontrolled reaction to take place, namely, an almost explosive collapse of the shell.

Since the shell rigidity is inadequate to maintain equilibrium, then some additional force must be introduced, if a sudden collapse is to be prevented or if it is desired to control the rate of collapse. If this force is related to the external force through the mechanism of the shell rigidity, then at the point of incipient buckling a null balance must exist such that for each incremental increase in external load an equal and opposite increase is developed by the restoring force, thus maintaining equilibrium.

From this reasoning we may postulate the following thesis which is the basis for the differential-pressure test. If a closed shell subjected to external pressure is filled with a compressible fluid, such as water, the point of incipient buckling of the shell may be detected by observing the point at which the difference between the external and internal pressures becomes constant. Furthermore, the extent of shell deformation after buckling is started may be controlled by regulating the external pressure acting on the shell until a state of yield exists.

The plot in *Fig.* 1 illustrates the theoretical pressure curve which the test method yields and relates the various portions of this curve to the stress-strain curve of the material. In the region *O* to *A* the specimen undergoes a uniform contraction. At point A the specimen starts to buckle because of elastic instability. As the external pressure is increased, the shell deforms until the internal pressure is increased just sufficiently to regain equilibrium with the external pressure. Thus, if the external pressure is increased 10 psi, the internal pressure increases 10 psi. Consequently, the difference between the external and internal pressures becomes constant and the curve between point A and C is horizontal. Although between A and B the differential pressure is constant, the specimen is experiencing a bending strain as the surface warps in addition to the uniform contraction. Thus at point B the specimen deformation is sufficient to have reached the elastic limit of the shell material.

It is significant to note, however, that if the external pressure is released at any point prior to B, no permanent deformation of the shell will result since the action is entirely elastic. Consequently, this procedure represents a nondestructive method for determining the incipient buckling pressure of the shell. Furthermore, it is equally applicable to shells of any geometric configuration, material, or

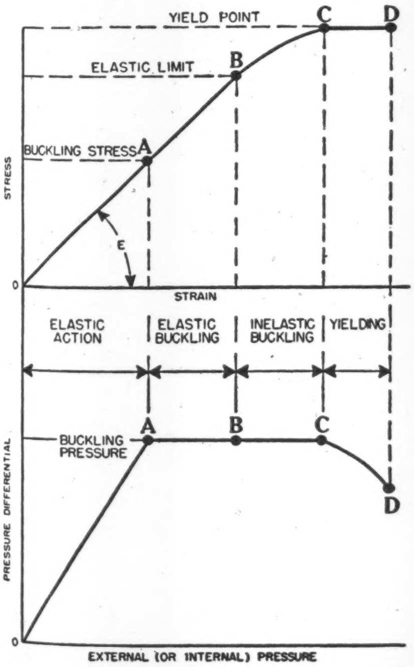
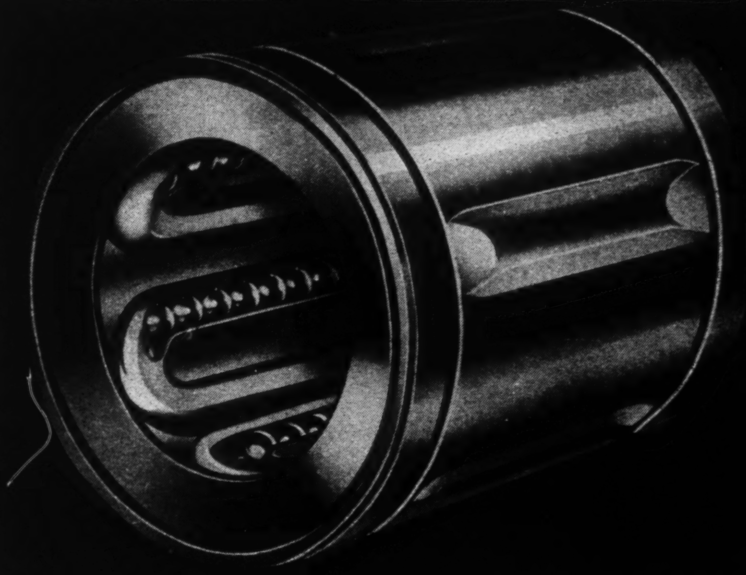


Fig. 1 — Comparison of theoretical differential-pressure test and stress strain curves

BALL BUSHING



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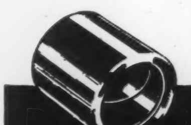

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Also manufacturers of NYLINED Bearings — DuPont NYLON within a metal sleeve—for rotation and reciprocation.

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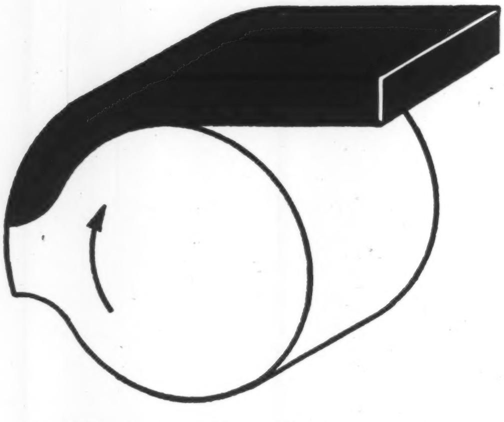

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ROTARY POWER

ones having internal ribs, frames, or bulkheads.

Between point B and C, inelastic buckling takes place until point C, which represents the yield point of the material, is reached. Beyond point C the specimen, if the material is ductile, continues to deform inwardly even though the external pressure is maintained nearly constant. This deflection causes a substantial increase in the internal pressure and since the external pressure remains nearly constant, the differential pressure must decrease. If the material is brittle or if the yield point and ultimate strength are nearly the same, then sudden and uncontrolled failure of the specimen will occur in the region of point C.

Test Equipment: The experimental apparatus necessary to perform a differential pressure test is simply a pressure vessel to contain the shell and two pressure gages to monitor the internal and external pressures. If manual plotting of the data is used, the constancy of the differential pressure is readily detected by observing when the second difference in the external and internal pressures approaches zero. It has been found that personal errors and the labor involved can be reduced substantially by producing a Cartesian plot of the pressure relationships by means of an autographic $(X-Y)$ recorder. Commercial $X-Y$ or function plotters have recently become available.

Applications: The differential-pressure test is uniquely applicable for determinations of incipient buckling of thin shells subjected to external pressure. The incipient-buckling pressure is the maximum unit strength of the shell and, moreover, is the maximum external pressure, within the limits of experimental error, which the shell can sustain before total collapse, if the shell is not internally supported by a liquid or solid filling material. Experimental support of this conclusion has been demonstrated by over a hundred tests made at the Naval Ordnance Laboratory on a variety of geometric shapes, materials of construction, and pres-

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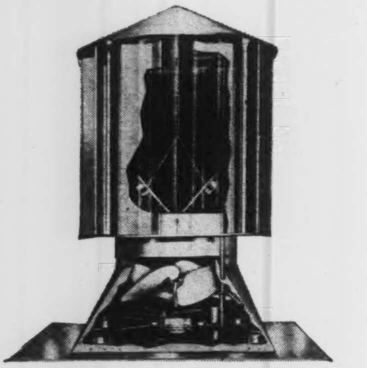
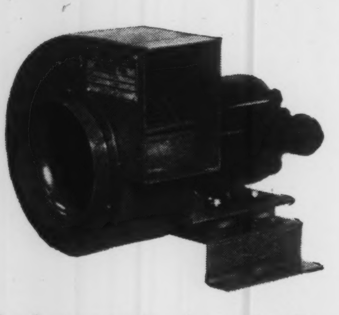
SHOCK AND VIBRATION NEWS

Exhaust Fans Quieted by Vibration Isolators



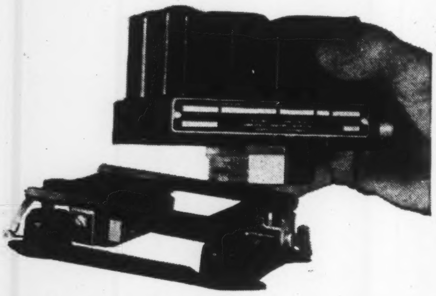
The problem of motor and fan noise is successfully overcome in the Breidert Air-X-Hauster by use of four air-damped Barrymounts that support the low-speed motor and fan assembly. These isolators absorb the motor and fan vibration, keeping it from reaching building members or metal ducts along which it would otherwise be carried or amplified. To assure adequate isolation, the mountings used were type 990 Barrymounts having a natural frequency of only 8 cps.



Another example of use for Barrymounts in ventilating systems is with the high-speed Westinghouse-Sturtevant multi-vane, railway car fan. Here they isolate fan vibration for quieter operation and protect the assembly from the shocks incidental to mobile service. In this application, type C-2000 Barrymounts were used to provide protection against forces applied laterally as well as vertically.

Your vibration or noise problem may be solved by a simple application of Barrymounts. Ask our Field Engineering Department; they'll gladly help you. Or write for Catalog 504-B, describing Barrymounts for a wide variety of uses.

Miniaturized Vibration Isolators Help Cut Space and Weight in Fuel-Gauge Power Unit



70% size reduction and 50% weight reduction — with no loss of performance — is the effective miniaturization obtained in the new Minneapolis-Honeywell aircraft-fuel-gauge power unit. Miniature, air-damped Barrymounts, Type 6465, helped M-H engineers in this achievement.

These vibration isolators, in which size and weight have been cut while operating characteristics have been maintained, will help you redesign for miniaturization.

Check these useful features of miniaturized Barrymounts.

Light weight — only 5/16 ounce each.

Small size — 1" diameter 11/32" loaded height.

Resonant frequency — 9 cps

Transmissibility at resonance — 3

Wide load range — 0.1-3 pounds

4 different styles available — for plate or stand-off mounting.

Write for data sheets 605 and 606 giving details of dimensions and load ratings.

FREE CATALOGS

- 523-A — Air-damped Barrymounts for aircraft service; also mounting bases and instrument mountings.
- 509-A — ALL-METL Barrymounts and mounting bases for unusual airborne applications.
- 504-B — Shock mounts and vibration isolators for marine, mobile, and industrial uses.
- 607 — How to cut maintenance costs by using Barrymounts with punch presses.

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sure ranges. This test has been adopted as a standard test method by this organization.

Because of the nondestructive feature of the differential test, proof loading may be conducted to the point of incipient buckling, thereby establishing the safety margin inherent in any given design. Where expensive or "one-of-a-kind" specimens are encountered this test offers an economical and scientific method to evaluate the efficacy of a given structure.

The differential-pressure test readily permits the detection of even the slightest leak by the nonlinear change in the differential-pressure curve during the early stages of the test. Thus a leakage and proof test can be conducted simultaneously with resulting economy. Also, there is some evidence that an advantageous "working" of fabricated thin shells can be achieved through repetitive application of the test.

For an ideal cylindrical shell the elastic portion of the differential pressure curve is a straight line. By means of equations (given in the original paper) it is possible to calculate any one of the elastic moduli, provided proper values for the other two are know. The most valuable calculation is that of an "effective compressive modulus" for the shell material. This calculation is particularly applicable for plastic shells which exhibit an effective compressive modulus substantially different from that obtained by routine mechanical tests on standard test specimens. The precision of the result obtained by using this approach is dictated almost entirely by the degree to which the experiment can be idealized.

This test yields results within 10 per cent of external pressure tests without destroying the sample. Its apparent limitations generally can be circumvented by slight modifications in experimental procedure. Substantial economies can be effected through its use.

From a paper entitled "A Nondestructive Differential-Pressure Test for Thin Shells" presented at ASME Fall Meeting in Chicago, Ill., September 1952.

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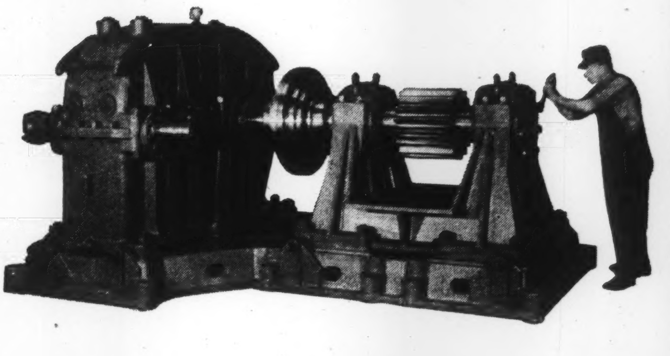

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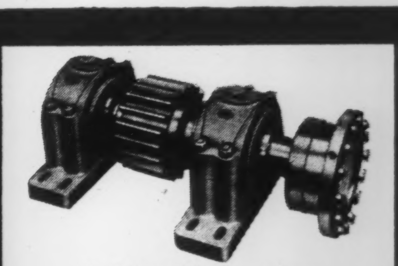

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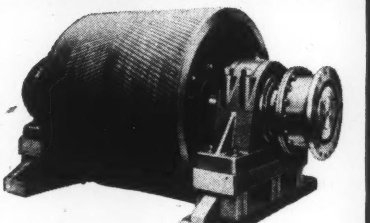

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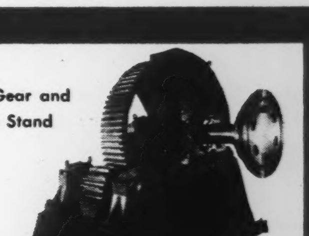

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Paint Remover: Consists of two skids under which is mounted a Calrod tubular heater rated at 1000 w, 115 v. In use the device is pushed along a painted surface, and heat from the Calrod unit causes the paint to soften and blister so that it can be removed with a putty knife. Skids keep heat a safe and constant distance from the painted surface; two metal reflectors keep the plastic handle cool. Complete device weighs 2¼ lb; is 6½ in. long. *General Electric Co., Schenectady, N. Y.*

Materials Handling

Materials Lift: Liftveyor enables clean-cut wide shearing to 0.005-in. regardless of material. Eliminates flexing; sheet is supported with air-operated plungers while sheet edge is against back gage. Conveys sheet beyond shear frame. Can be used with small or large shearing devices. Standard or heavy duty models available for sheet to ⅛-in. thick, and for plate to ½-in. thick. *Fried Steel Equipment Mfg. Corp., New York, N. Y.*

Fork Lift Truck: Improved 15,000-lb capacity Yardlift-150 features increased horsepower, lighter weight and better hydraulic steering. New power plant develops more horsepower at fewer rpm; weight reduction of 2300 lb provides increased flotation; improved hydraulic steering makes operation

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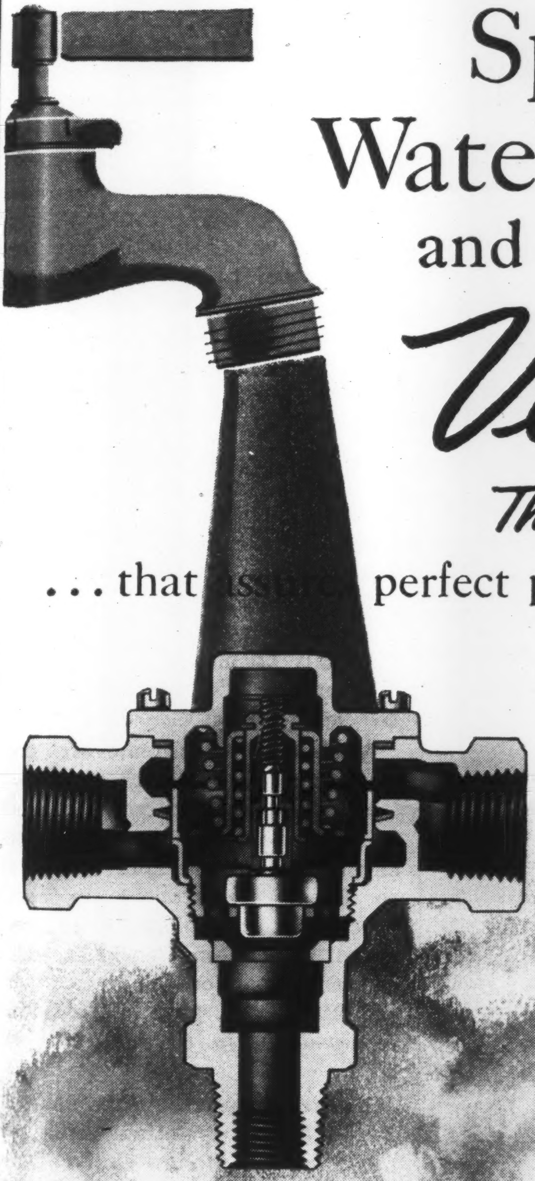

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- ★ Not affected by variations in pressure of either hot or cold water supply
- ★ Valve shuts off water flow if either water supply should fail
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15 lbs. pressure ...	**40 lbs. pressure ...**
8.5 gals. per min.	**14.0 gals. per min.**

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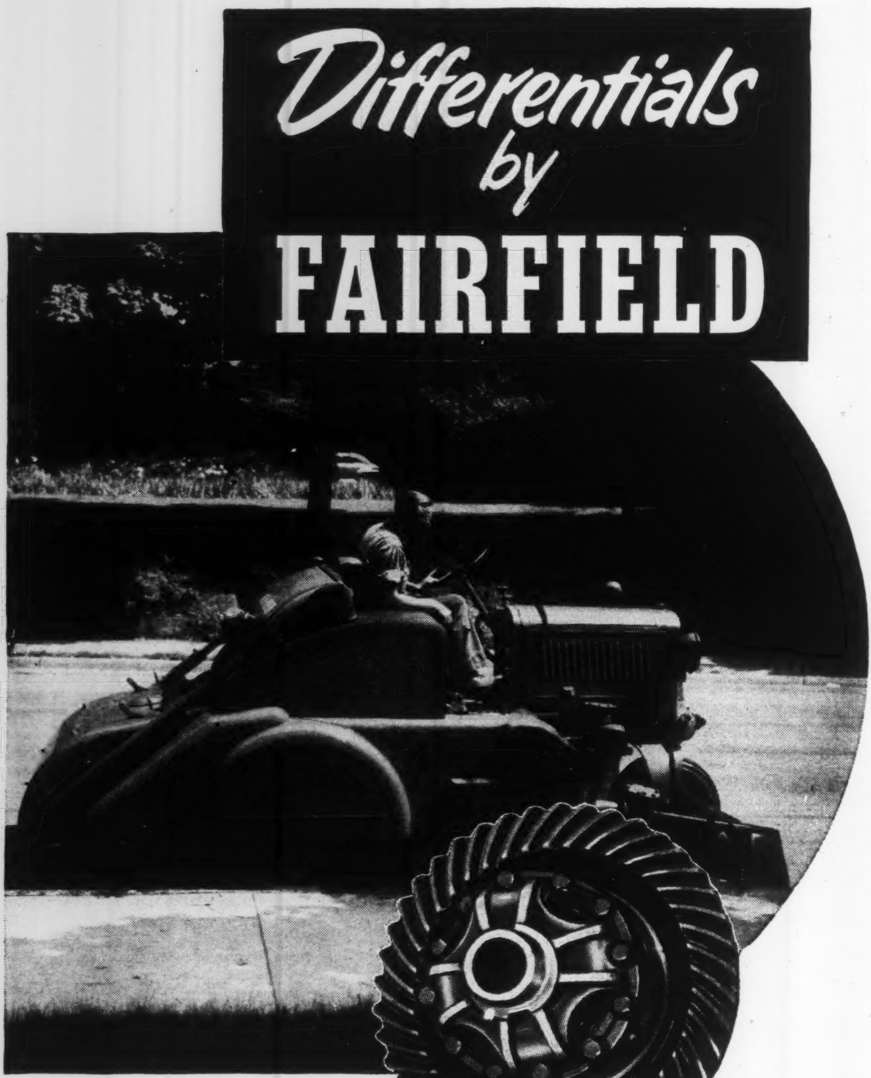

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easier. In the event of motor stoppage, steering can be accomplished mechanically. A separate hydraulic system is used for power steering. Truck has pivoted steering axle. Driver's view is increased by narrower fork bars and larger opening between upright channels and lift cylinders used on the truck. *Clark Equipment Co., Industrial Truck Div., Battle Creek, Mich.*

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Mechanical Strip Remover: Stripveyor for use with either small or large shearing devices. Automatically picks up cut strips beyond the shear bed. Adjustable height up to 45-in., synchronous to shear speed, can handle any gage sheet metal up to 3/8-in. in widths which can be accommodated by a standard 24-in. back gage. *Fried Steel Equipment Mfg. Corp., New York, N. Y.*

Electric Hoist: Available in 1, 2 and 5-ton capacities. Has center drum with hollow shaft. Drive shaft from motor passes through center of this shaft to input shaft of the gear. Two eccentrics which operate gear mechanism are mounted on input shaft. Electric brake is on the outer end of the gear box. *Universal Gear Corp., Indianapolis, Ind.*

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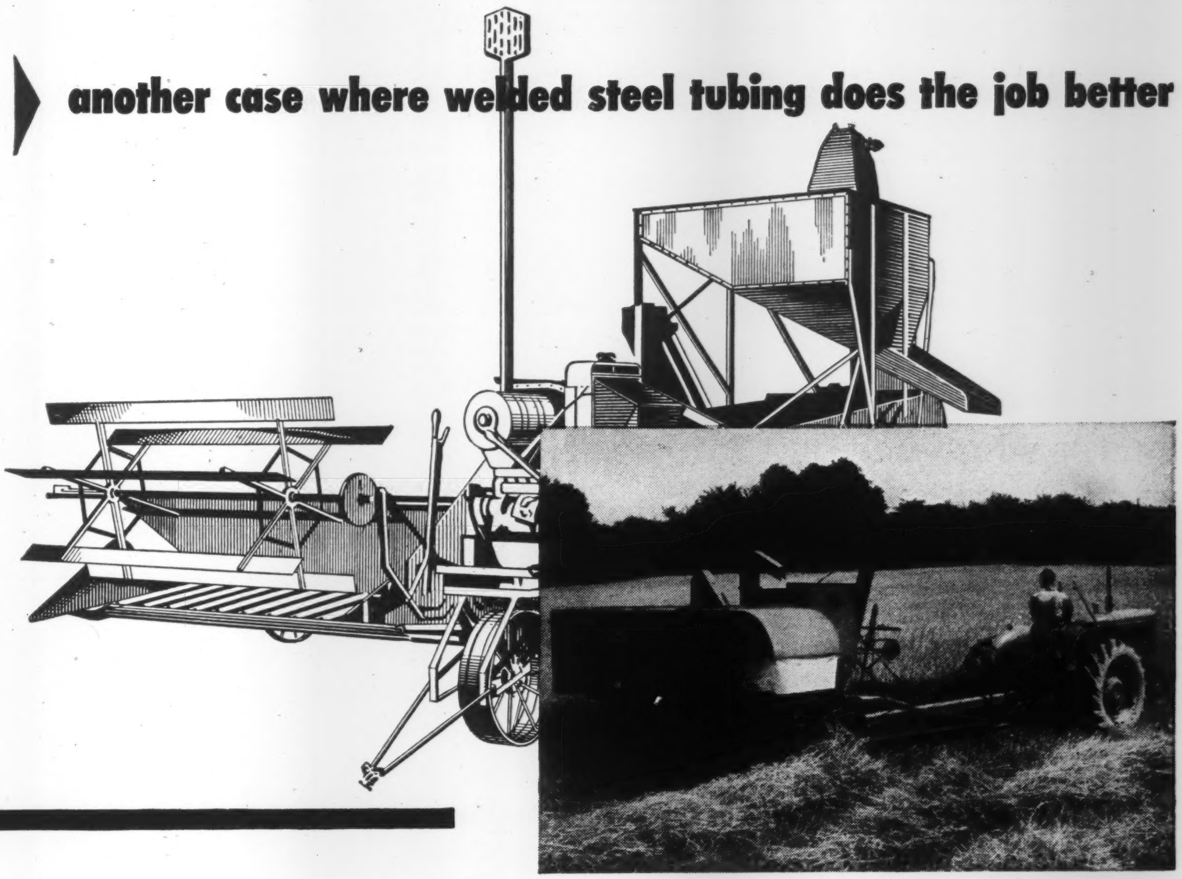

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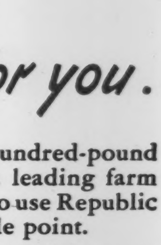

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original position after drilling is completed. Cycling, which can be either automatic or semiautomatic, is controlled hydraulically with electrical controls. Machines have self-contained oil and coolant reservoirs, pumps, hydraulic controls and electric motors. *Zagar Tool Inc., Cleveland, O.*

Portable Machine Carriage: Oxweld CM-45 for straight-line, bevel and circle cutting of metals. Cuts bevels at almost any angle, top or bottom, either in straight lines or circles, with 2 to 54-in. diameters. Flame-treating jobs, such as low-temperature stress relieving, flame-hardening, and flame softening, can be done with suitable apparatus mounted on machine. Can be used to mechanize welding jobs. Powered by heavy-duty electric reversible motor. Centrifugal-type governor covers a stepless speed range of 4 to 32 in. per minute; other speeds possible if special motor gear heads are used. Simple gearing system and mechanical clutch permit disengaging gears for free wheeling. Unit weighs $33\frac{1}{4}$ lb complete with blowpipe. *Linde Air Products Co., Div. of Union Carbide and Carbon Corp., New York, N. Y.*

Punch Press: Model 3060, with 30-ton capacity. Features include positive brake and counterbalance, all herringbone gears, four-point engaging clutch, electrically operated clutch control. Can be converted into power squaring shear. Specifications: bed size, $15\frac{1}{2}$ by $61\frac{3}{4}$ in.; ram size, 10 by $60\frac{3}{4}$ in.; maximum shut die height to order, 24 in.; ratio of gearing, 6 to 1. Makes 80 strokes per minute. Floor space required, 23 by 103 in.; weight, 5400 lb. *Diamond Machine Tool Co., Los Angeles, Calif.*

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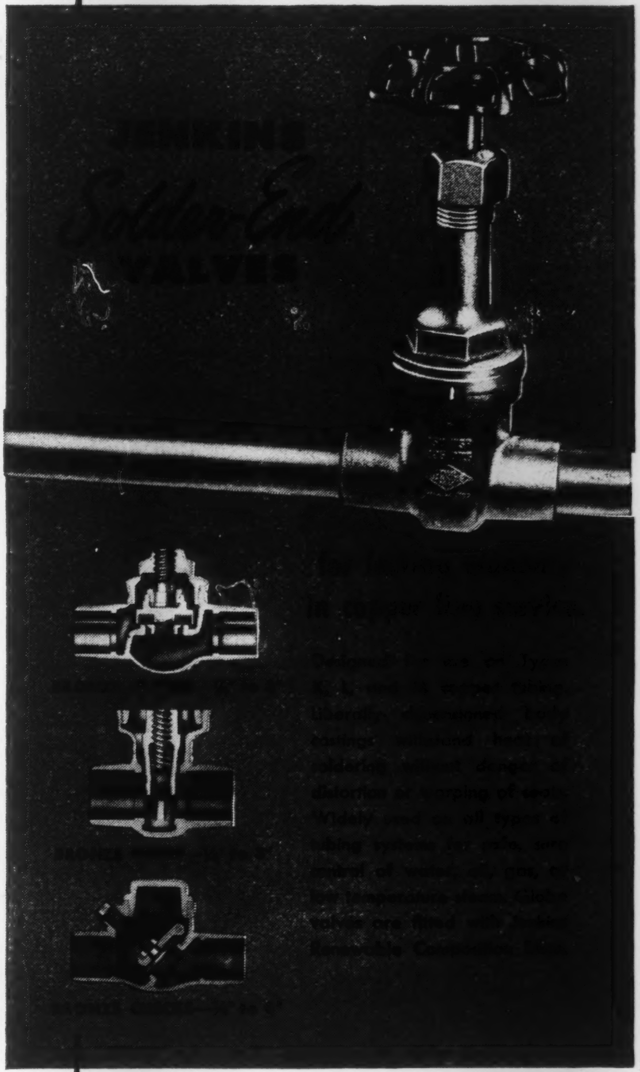

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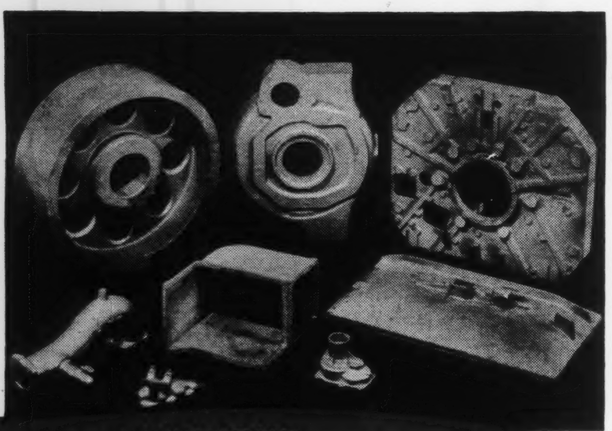

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Well-Cast Ampco Bronze Castings.

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THE WELLMAN BRONZE & ALUMINUM CO.

DEPT. 10, 12800 SHAKER BLVD., CLEVELAND 20, OHIO

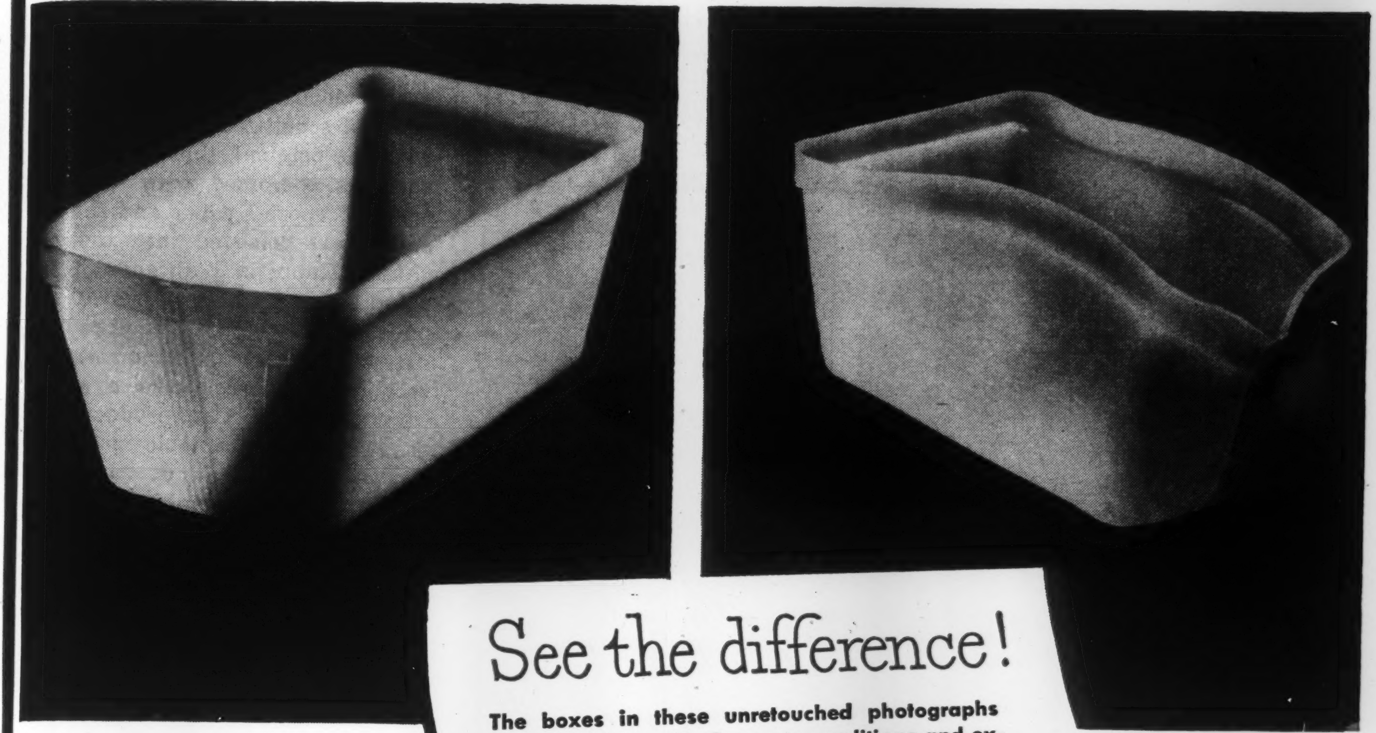
cool enough to be removed without danger of oxidation. Also produces controlled oxide coating often desired to reduce corrosion or wear and to produce blue-gray or blue-black appearance. Protective atmosphere is used to maintain bright surface during tempering or annealing operation prior to controlled oxidation cycle; oxidation process can be controlled irrespective of tempering or annealing portions of cycle. After load reaches oxidation temperature, flow of protective gas is discontinued and water introduced into unit. Work is then removed from furnace and air cooled or liquid quenched. Unit can also be used in tempering nonferrous metals, since uniform temperature is maintained. *Ipsen Industries Inc., Rockford, Ill.*

Press Brake: Can be used for shallow draw work as well as conventional press brake work. Has double plate bed; 30 in. width, 15 ft 8 in. overall length. Fourteen 6-in. air cylinders are mounted between plates for operating draw rings, knockout bars, and similar units. Speed, 23 strokes per minute. Has removable ram angles for press or brake operation and air counterbalances and horns on each end of bed and ram. *The Cincinnati Shaper Co., Cincinnati, O.*

End Fnishing Machine: Bench type. Enables operator to clamp and feed work to cutting tools with single forward movement of a hand lever. Fast stock handling and loading is possible. Workpieces are automatically released by reversing hand lever. Adjustable swing-type stop operated by feed rack provides fast and accurate positioning and gaging for depth of cut. Changeover can usually be accomplished in one minute. Handles stock up to 2-in. in diameter. Has three-speed sheave, ½-hp motor. Can also handle single-point boring, light forming and turning operations. *Pines Engineering Co. Inc., Aurora, Ill.*

Office Equipment

Photo Copy Machine: Copi-Stat machine makes dry reproductions. Copies typed, written, printed or



See the difference!

The boxes in these unretouched photographs were molded under the same conditions and exposed to a temperature of 212°F. The box on the left, made from Koppers MC 409, showed little or no distortion after 30 minutes at this temperature. The box on the right, made from a widely used commercial modified polystyrene, showed major distortion within 10 minutes.

high heat resistance in a modified polystyrene...

KOPPERS MC 409

- Here's the high-heat modified polystyrene that the industry has long wanted . . . Koppers MC 409.

This new material combines three important advantages . . . higher heat resistance *(up to 198°F.*)* . . . the toughness and shock resistance of modified polystyrene . . . and the desirable finish and molding characteristics of regular polystyrene. MC 409's excellent heat resistance is comparable to that of Koppers well known Polystyrene 8.

These qualities make MC 409 an ideal material for radio cabinets, battery cases, washing machine and refrigerator parts, toys, housewares, brush handles and, in fact, any molded or extruded polystyrene product subjected to heat.

Koppers MC 409 makes possible sturdy, shock resistant, plastic products that withstand the high temperatures found in show windows, dishwashers and automobiles, where other modified polystyrenes sag and shrink. Tests prove that on exposure to boiling water MC 409 will show low deformation with a minimum of shrinkage.

FOR FREE SAMPLES for testing in your laboratory and for Technical Bulletin C-2-161-TR describing the properties and characteristics of MC 409, write, wire or phone Koppers Company, Inc., Chemical Division, Dept. MD-122, Pittsburgh 19, Pa.

**A.S.T.M. D-648-45T.*

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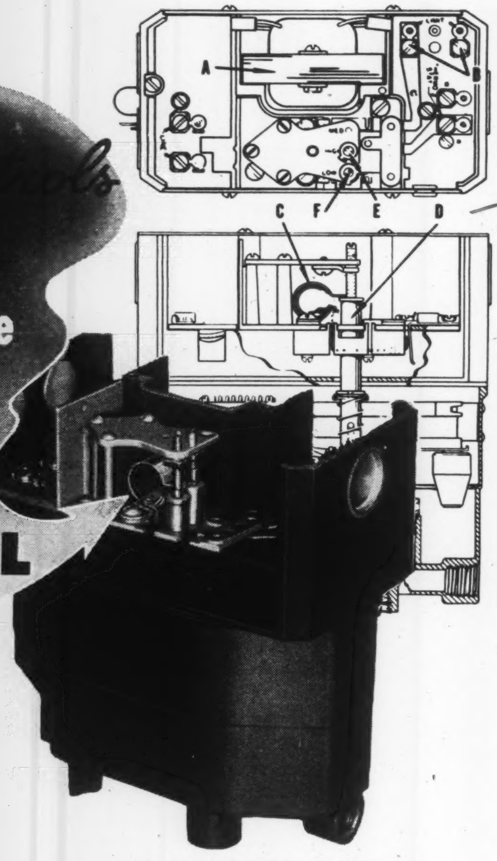
end furnace smoke and fumes—

with CHACE BIMETAL



Product of: Detroit Controls Corporation
Established in 1877 as Detroit Lubricator Company

The CRC-239-F Series Detroit Furnace Controls are electrically operated float valves designed to control the flow of fuel to vaporizing pot type burners in accordance with the demands of an electric wall type thermostat. They incorporate in one compact unit all the mechanism necessary for thermostatically operating the flow control valve and switch mechanism which control the booster fan. This precise regulation of fuel eliminates smoke and carbon formations. The movement of the metering stem which controls the flow of oil to the burner is dependent on Chace Thermostatic Bimetal.

When the thermostat calls for heat it completes the circuit from the 24 volt secondary of the built-in transformer "A" through the limit switch connected to terminals "B" and a heat motor "C". When the heat motor is thus energized it operates the metering stem "D", allowing it to rise to high fire position. This stem moves to low fire position when thermostat opens the circuit. The limits within which the metering stem travels are set by adjusting screws "E", high fire, and "F", low fire.

If the actuating element for your new control device is thermostatic bimetal, Chace has the equipment and qualifications for fabricating it ready for assembly. Our 29 types of bimetal are available in strips, coils, random long lengths and welded or brazed sub-assemblies. We also provide specialized tooling for fabricating to your designs; our application engineers are available for consultation. Write for a copy of our new 32-page booklet, "Successful Applications of Chace Thermostatic Bimetal," containing condensed engineering data.

IT BENDS WITH THE HEAT

W. M. CHACE CO.
Thermostatic Bimetal
1616 BEARD AVE., DETROIT, MICH.

drawn documents. In operation a sheet of sensitized paper is exposed with the original, then the exposed sheet is combined with a second sheet of special paper and the two sheets are inserted into the machine. Knobs at both ends of machine are turned slowly for 10 seconds. The two sheets emerge from machine after approximately 15 seconds and are peeled apart to produce copy. Can produce two-sided copies. Available in 8½, 11 and 17-in. sizes, all of which can be equipped with motors for automatic operation. *General Photo Products Co. Inc., Chatham, N. J.*

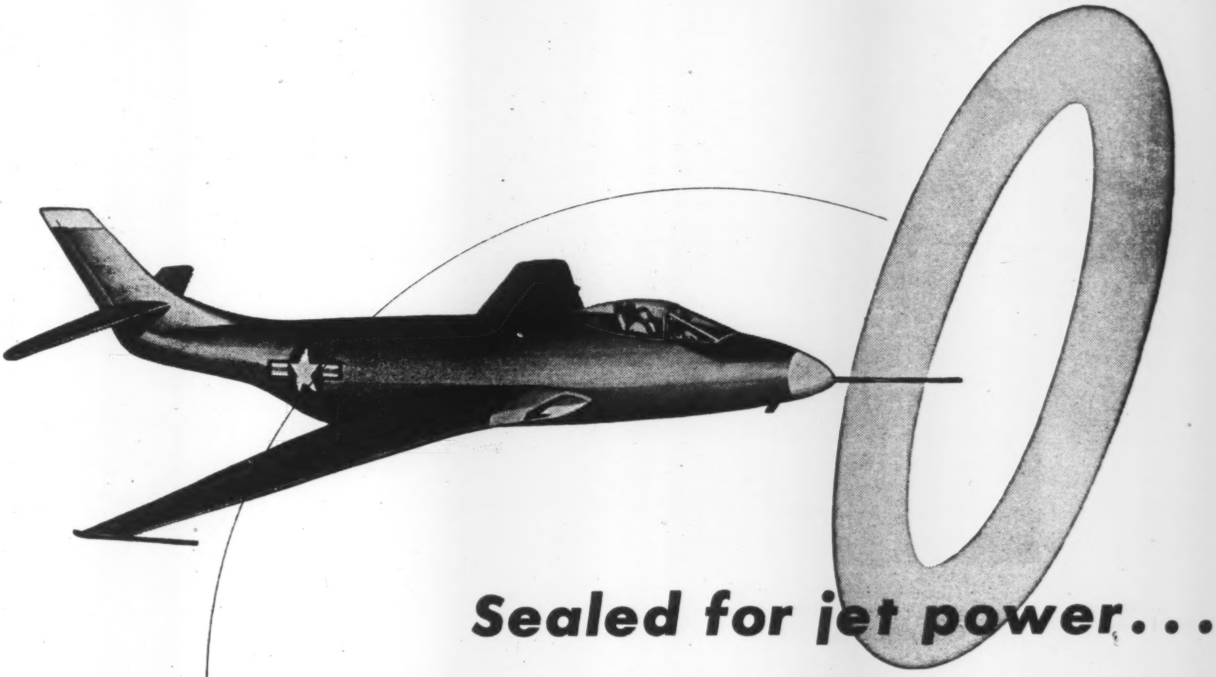
Typewriter: Features dual tab control, both finger and palm tabulation. Tension of carriage can be adjusted to suit individual jobs by turning an indicating dial on left side of machine. Brown in color, green plastic non-glare keys. Has extra key which can be furnished with any two of five characters or a personalized symbol. *Royal Typewriter Co. Inc., New York, N. Y.*

Plant Equipment

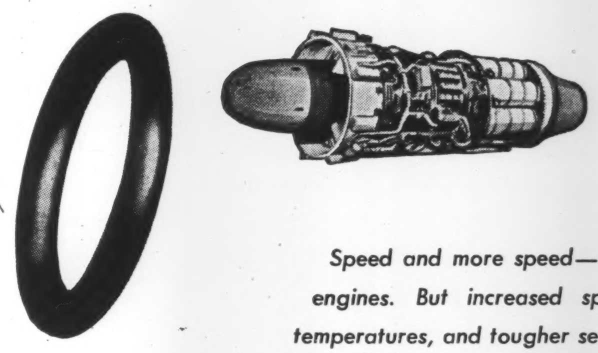
DC Power Supply: Model M30 has dc current rating of 150 ma. Has low-voltage ac output of 6.3 v at 6 amps. Voltage regulation is within 0.5 per cent for voltages between 30 and 325 v from no load to full load, and ripple is less than 2 mv. Also has two 3-in. rectangular meters. *Perkin Engineering Corp. El Segundo, Calif.*

Dust Collector: Model 30ND50 has rated capacity of 3630 cfm at 6-in. static suction on an 8-in. diameter pipe. Employs standard size cyclone separator which removes dust and dirt from air. Has standard 12-cu ft dust storage capacity. Unit can be supplied with either an extension or hopper bottom if it is to be used for woodworking operations or other jobs involving very large amounts of collected dust. Powered by 5-hp motor which operates on either 220 or 440-v, three-phase, 60-cycle power. *Aget-Detroit Co., Ann Arbor, Mich.*

Chaser Sharpening Machine: Universal bench type unit for both tangent and radial die chasers.



Sealed for jet power....



Speed and more speed—that's the goal for designers of today's jet engines. But increased speed calls for increased power, higher temperatures, and tougher service conditions.

That's why manufacturers turn to LINEAR precision moulded Silicone "O" rings for critical sealing in pressurized jet engine components. A typical engine utilizes these seals in the relief valve in the engine's front frame, and between the fuel flow divider and oil cooler. LINEAR Silicone "O" rings offer major sealing advantages over other elastomers because of their high resistance to oil vapors and low compression set at elevated temperatures.

In many other products, from steam irons to searchlights, LINEAR Silicone "O" rings have provided resilient sealing against oxidation, prolonged weathering or temperature extremes. A complete range of Silicone rubber stocks to meet AMS-3301A to AMS-3305A requirements or for other tough conditions is available. To simplify design—to lower costs—consult LINEAR for all your sealing needs.

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LINEAR, Inc., STATE ROAD & LEVICK ST., PHILA. 35, PA.

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SPECIAL GAGES

Dial Indicators
For every gaging requirement—over 80 different models, ranges, sizes, graduations, styles.

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Combine Dial Indicator graduations and tolerance signals for ultra-high speed gaging.

Continuous-measuring Gages
Automatic control of processes using electronic, electrical, air, or mechanical gaging systems.

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Operated electrically, electronically, by air, or combinations. Designed for manual, semi, or fully automatic loading and unloading.

Designing and building dimensional gages requires a definite type of experience and know how in what makes a gage measure precisely.

Here at Federal this very practical and long experience covers a wide range of gaging requirements which can't be equalled anywhere in the world . . . and it's ready to serve you. Over 25,000 gage designs are in our files and one of them can quite possibly be adapted for your requirements at less cost than the trial and error method so often used.

We will gladly work closely with *you* on your dimensional gaging requirements, for the *quick* answer . . . the *right* answer. Bring your gaging problems to Federal and take advantage of our engineering experience. Send full details and blueprints to Federal Products Corporation, 3012 Eddy Street, Providence 1, R. I.

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Will duplicate desired grinds repeatedly. Swinging arm is controlled by adjustable stop screw to maintain positive stop points during top rake grinding. Cross-feed handwheel with graduated micrometer dial controls infeed of swinging arm and regulates amount of stock removed. Requires 14 by 28 in. of bench space. *Jones & Lamson Machine Co., Springfield, Vt.*

28 in. of bench space. *Jones and Lamson Machine Co., Springfield, Vt.*

Portable Compressors: Three sizes: 105, 210 and 315 cfm. Feature smaller dimensions, less weight and lower discharge temperatures than conventional portable compressors. Continuous rotary action provides steady flow of air without pulsations or vibrations. Air output is controlled over full range from 0 to 100 per cent capacity. Air pressure stays between 100 and 110 psi throughout entire capacity range. Comparatively light weight provides easy maneuverability in rough terrain. *Ingersoll-Rand Co., New York, N. Y.*

Sump Tank Cleaner: Model 20-T Series NA, designed to remove dirty coolant or cutting oil as well as chips and sludge from sump tanks of machine tools. Operates on high-vacuum principle; only air passes through the pump unit. Made in tank capacities of 100, 150 and 200 gallons. Each tank has sludge compartment containing a removable 100-lb capacity sludge basket. Pumping unit, consisting of a vacuum pump driven by a ½-hp motor, has automatic controls which shut the pump unit off when the tank is filled. Pumping rate is 25 to 30 gpm on average oil or coolant. *W. R. Carnes Co., Verona, Wis.*

Processing

Roller-Hearth Furnace: Electric Model RH-68 for heat treating moderately large items or heavy loads, such as tools, dies, etc. Counterbalance drop-type door is equipped with a roller mounted on the top edge and thus provides a continuous conveyor. Designed for normal operating temperatures of 1400 F, maximum 1500 F. Operates on

20 kw; 220-v, 60-cycle, single-phase current. Can be adapted to specific requirements with various types of heating elements and automatic temperature controls. Overall size, 42 in. wide, 48 in. deep, 75 in. high; chamber size, 15 in. wide, 30 in. deep, 15 in. high; has roller extension or conveyor 36 in. long by 15 in. wide, placed at working height of 30 in. *Pereny Equipment Co., Columbus, O.*

Induction Heater: High frequency Model LI-50A-1 for heating and fabricating operations which require production brazing, soldering, hardening, forging or shrink fitting. Provides more than 50 kw at 400,000 cycles per second on 100 per cent duty cycle. Features built-in closed water system which circulates temperature-controlled water to oscillator tube and tank coils. Size, 96 in. wide, 68 in. deep, 80 in. high; weight, 5400 lb. without accessories. *Lindberg Engineering Co., Chicago, Ill.*

Testing and Inspection

Salt Spray Testing Cabinet: For "fog-type" spray testing of all ferrous and nonferrous metals, organic and inorganic coatings. Lucite cabinet, said to be inert to all solutions and gases used in the complete range of this type of testing, is light in weight, portable, transparent for observing operations, and a good insulator for maintaining accurate operating temperatures. Size of cabinet, 36 in. by 24 in. by 36 in. ID. *Singleton Co., Cleveland, O.*

Materials Tester: Hand-operated Multi-Low-Range machine which can apply a load to specimens with extremely slow speed. Load can be stopped instantly. Does not require variable-speed drive or other electrical controls. Accuracy guaranteed to within 0.5 per cent to meet ASTM requirements. Employs pendulum-type mechanism set in machined bearings. Includes set of gripping fixtures for flat specimens up to $\frac{1}{8}$-in. thick by $1\frac{1}{4}$ in. wide which can be removed and replaced with a variety of other standard grips for wire, paper, wood, adhesives, rubber, springs,

Machine it or blank it . . .
Make one part or millions . . .
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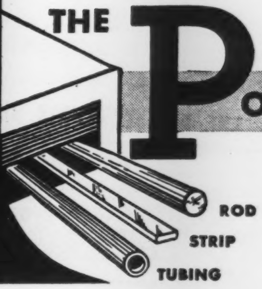

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IT'S A DOZER!
STRAIT-LINE

HYDRECO SELECTOR VALVE PUTS LOW-COST DOUBLE DUTY IN "STRAIT-LINE" LOADER

Maine Steel, Inc. engineers designed this Strait-Line Loader to do a MAN-SIZE job . . . at modest cost. They specified a HYDRECO Selector Valve to operate the loader and dozer alternately — and saved the cost of a second circuit.

HYDRECO Selector Valves can work for you, too, operating the auxiliary hydraulic equipment on your product . . . and cutting costs in original equipment or on-the-job installations. HYDRECO Selector Valves are made in capacities of 5, 15, 25, and 50 gals./min. and for system pressures up to 1500 p.s.i.

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etc. Available with grip clearances of 14¾, 24, 36 and 48 in. Basic dial is calibrated with four individual scales: 10-lb range with ½-lb divisions; 25-lb range with 1-lb divisions; 50-lb range with 2-lb divisions; 100-lb range with 5-lb divisions. Supplementary dial available calibrated for 0 to 300 lb with 1-lb divisions. Pointer remains at peak load after specimen breaks. Overall height, 64 in.; net weight, 170 lb. *W. C. Dillon & Co. Inc., Forest Park, Ill.*

Dynamic Balancing Machine: Portable model 652 Vibratron for analysis, evaluation and correction of vibration. Measures accurately and without computation the amplitude and frequency of vibration and, by means of a stroboscopic light, discovers the source of vibration. Consists essentially of vibration pickup, multichannel electronic circuit and stroboscopic lamp. Can also be used for maintenance and production testing. By means of a four-step switch in amplitude circuit, meter readings can be obtained in full scale from 0.0001 to 0.1 in. peak to peak. Features rugged and sensitive velocity type vibration pickup which will withstand rough treatment without failure or loss of accuracy. Pickup output is 82 mv at 0.001-in. deflection at 60 cps. Operates on 110-v, 60-cycle current. *International Research and Development Corp., Columbus, O.*

Space Oscillator: For exciting one, two or three directional mechanical vibrations; for fatigue testing of specimens or structural members; and for determining dynamic characteristics of materials. Displacement, velocity and acceleration are continuously variable in magnitude, direction and action line without interrupting test procedure or repositioning specimen. Oscillator consists of housing which supports three parallel shafts. Each shaft has a set of weights whose center of gravity may be shifted eccentrically, producing a centrifugal force. Also variable is the angular relationship between the centrifugal forces produced by the outside sets of weights with respect to the centrifugal force ex-

weight—1 7/8 oz.
size—2 1/32 x 3 1/32 x 1 1/2"
studs arranged on any surface
coil resistance to 5000 ohms
AUTOMATIC ELECTRIC
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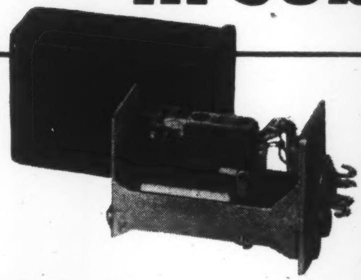
SWITCHES

now! relay veteran hermetically sealed in *sub-miniature* enclosure



AUTOMATIC ELECTRIC sub-miniature relay

- *Developed especially for aircraft service*
- *Designed to meet or better all provisions of MIL-R-6106*
- *Dependable contact operation under vibration up to 10.5 G's*

Specifications

Contact Arrangements—2 Form "C" (DPDT) or equivalent
Operating Voltage—up to 115 volts, d.c. only
Operating Time—range 0.002-0.016 seconds
Release Time—range 0.005-025 seconds
Contacts—Normally twin, Code 0-20 ga. Will carry up to 100 watts (maximum 2 amperes) inductive or non-inductive load. Makes or breaks 50 watts (maximum 1 ampere) inductive load, or 135 watts (maximum 1/2 ampere) non-inductive load.

When space, weight and atmospheric conditions are determining factors in relay selection, specify the popular Class "S" relay in this new Automatic Electric sub-miniature hermetic enclosure.

This bantam-sized, feather-weight relay is now available in this new small housing (approximately 3 cu. in.)—hermetically sealed in an inert atmosphere of dry nitrogen. It has proved itself in aircraft and similar applications—and is specified wherever extreme shock, temperature or high levels of humidity require exceptional performance.

If your planning calls for a small, light, atmosphere-protected and tamper-proof relay of recognized ability, minimum inductance and maximum make-and-break speeds—specify this outstanding new member of Automatic Electric's relay group. For descriptive bulletin, write: Automatic Electric Sales Corporation, 1033 West Van Buren St., Chicago 7, Illinois. In Canada: Automatic Electric (Canada) Ltd., Toronto. Offices in principal cities.

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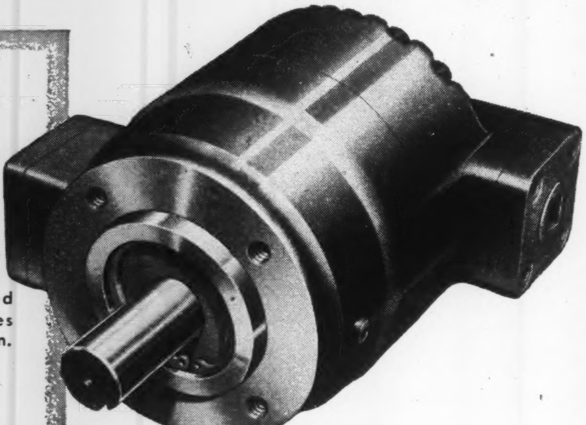
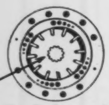
"The Finest Money Can Buy!"

in smoother, longer-lasting performance

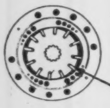


Because of:



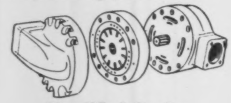
Radially Balanced Rotors

Dual, opposed inlet and exhaust porting provides radially balanced operation.



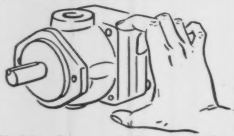
Hydraulically Balanced Vanes

Less load on cam ring . . . low loading characteristics at all operating pressures.



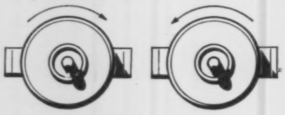
Simplified Design

Consisting of only three ruggedly built, close-coupled components. Pump/Motors assure extra stamina.



Highly Compact Construction

Delivering 7.5 gpm at 2000 psi, this typical Pump/Motor is only 4⅛" in width and height; only 8" long *including the shaft.*



Bi-directional Rotation

All Pump/Motors are quickly and easily convertible to counter-clockwise rotation, and operate with equal efficiency in either direction.

DENISON PUMP/MOTORS—*ready for either pump or motor use without alterations of any kind*—are designed and built to stand up longer, at full efficiency, under a wider range of applications calling for hard, continuous duty at 2000 psi.

Some of the features that give Pump/Motors this extra value are shown at left. In addition, their 3-unit construction makes it easy to alter the relation of inlet and exhaust porting for easiest installation. For better valving action, the heavy-duty Pump/Motor vanes feature dual, precision-machined sealing edges held in constant contact with the cam ring.

FOUR SIZES, each with a choice of interchangeable cam rings, offer pumping capacities from 2.7 to 70 gpm . . . or motor torque capacities from 13 to 257 pound-inches per 100 psi. *For smoother, longer-lasting, low-maintenance operation, specify Denison Pump/Motors.* Write for full details.

The DENISON Engineering Co.
1156 Dublin Road Columbus 16, Ohio

DENISON HydrOILics

PUMP/MOTOR

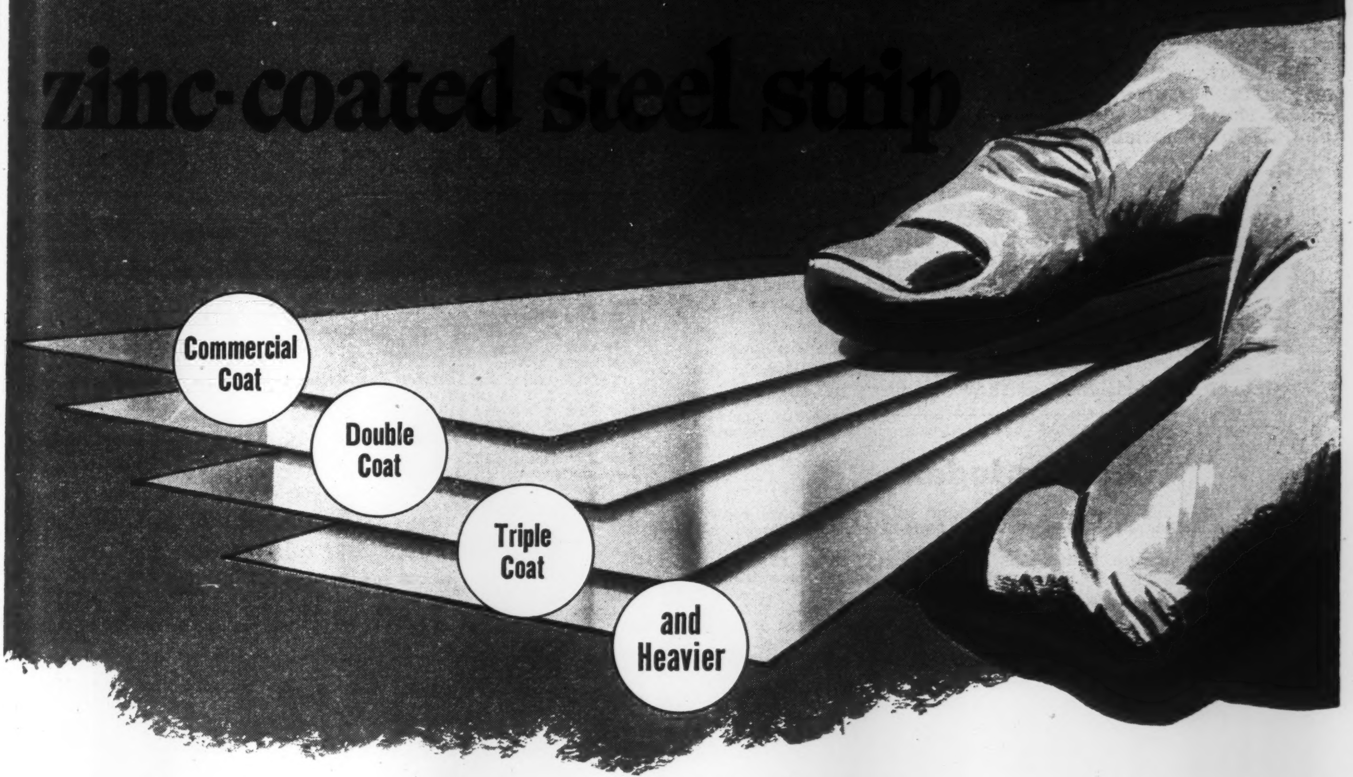
cited by the central set of weights; oscillator actually produces three forces. Rated capacity is 2000 lb at 15 cycles per second and 1000 lb at 60 cycles per second, with proportionately smaller forces over the range of 3½ to 15 cycles per second. Amplitudes varying from 0 to ½-in. are normally obtainable. *Buck Engineering Co. Inc., Freehold, N. J.*

Spring Tester: For testing loads and deflections of small compression and extension springs. Load range capacity is from ½ oz to 25 lb. Adaptable for both general purpose and production testing. Speed varies from 250 to 500 tests per hour. Tests springs with diameters up to 2 in. and lengths up to 10 in. Scale is accurate to within 0.25 per cent, meets National Bureau of Standards' requirements. Dial indicator with 1-in. capacity available to measure lengths and deflections to 0.001-in. *The Carlson Co., New York, N. Y.*

Circuit Breaker Tester: Portable Model CBT-1 for testing circuit breakers in electrical systems of aircraft. Determines length of time for circuit breaker under test to "trip out." Will test circuit breakers rated up to 150 amps on a 28-v, dc current. Test panel provides mountings for a dc voltmeter; dual scale 0 to 30 and 0 to 150-amp dc ammeter; 30-amp and 150-amp negative input terminal ports; dc ammeter range selector switch; 11 loading switches; and a 1000-second manual reset timer. *Greer Hydraulics Inc., Brooklyn, N. Y.*

Vacuum Tester: For testing such items as shaft seals, diaphragms, cylinders, bellows, castings, small fuel tanks, pneumatic valves of all types, manifolds, aircraft parts, magneto parts, plastics, rubber and graphite. Reveals porosity of surface fissures, tests lapped or ground surfaces, or surface flatness. Can also test sealing of complete assemblies and air cylinders. Small, portable; comprised of vacuum pump and instrument panel with attached testing plate. Standard plate size and composition may be varied to meet specific requirements. *Gits Bros. Mfg. Co., Chicago, Ill.*

Now you can get heavier than commercial electro-plated zinc-coated steel strip



When your production standards demand extra protection from corrosion you can get it now with the *double, triple,* and even *heavier* electrolytic zinc coated Thomas Strip. This cold-rolled strip steel has a dense, uniformly distributed peel-proof zinc coating that adds substantially to product life and appearance. Coated edges can be furnished in most sizes.

In addition to the extra heavy zinc coatings, Thomas has facilities to handle the heavier gauges of strip in coils or cut lengths—thickness limits up to .125″ (full range .005″ to .125″)—widths ¼″ to approximately 22″.

Thomas electro-plated zinc strip may be formed, bent, and drawn without affecting the bond or causing flaking. Now it is available in *commercial, double, triple,* and *heavier coatings.* It can be furnished bonderized in strip thicknesses of approximately .050 and lighter to provide extra adherence for paint, lacquer, and enamel. To learn how to put extra quality into your products with precoated Thomas Strip write today.

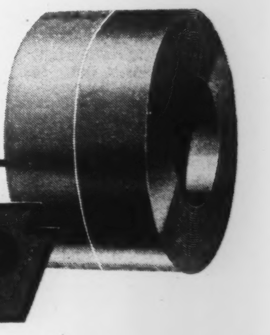
Cold-rolled strip steel electrolytically precoated with Zinc, Copper, Brass, Nickel, Lead-Alloy, and Chromium in Natural, Planished and Buffed Finishes—Hot Dip Tin and Lead Alloy Coated—Lacquer Coated in Colors—Annealed Spring Steel—Alloy Strip Steel—Uncoated Strip Steel. Carefully produced to your specifications.

Thomas Strip

a product of

Pittsburgh Steel Company

Thomas Strip Division • Warren, Ohio



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Volume 24—January to December

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The following key has been used to identify regular departmental features and articles of less than one page in length. Entries not identified are feature articles of more than one page in length.

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(Abstract)	Design Abstracts
(CD)	Contemporary Design
(Data Sheet)	Data Sheet
(EDE)	Engineering Department Equipment
(NP)	New Parts and Materials
(Patents)	Noteworthy Patents
(P&D)	Production and Design
(Roundup)	Engineering News Roundup
(Scanning)	Scanning the Field for Ideas
(Short)	Articles less than one page in length

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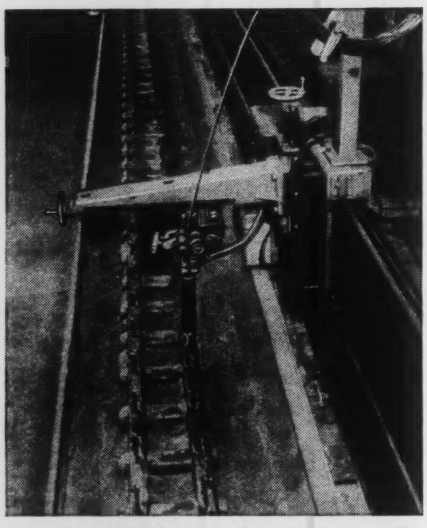
LINDE'S News of Metalworking

Worn Parts Rebuilt Economically by UNIONMELT Welding

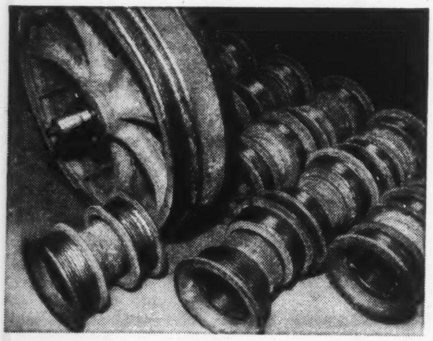
Repair of worn tractor parts is most practical and economical with specially developed fixtures on which standard UNIONMELT welding units are mounted. The metal deposited by UNIONMELT welding is so smooth that no grinding or finishing is required. Experience indicates that resurfaced areas will wear as long as new parts.

The Berkeley "Conservall" fixture is designed especially for rebuilding crawler tractor track links or rails without disassembling them. The track is placed in a trough and clamped in position. A LINDE side-beam carriage moves the UNIONMELT welding equipment over the positioned track and the welding of each link is automatically started, stopped, and accurately controlled. Rollers, idlers, sheaves, and other circular work can also be welded or resurfaced on another section of the machine.



Tractor rail links rebuilt in "Conservall" machine by UNIONMELT *welding. Cams automatically control welding action for each link.*

The "Leader" machine is also available for rebuilding both cylindrical and flat parts. Rollers are rebuilt on top of the machine. Larger parts, such as idlers, are mounted in the chuck at the side of the machine as shown. With the flat work attachment, parts such as disassembled track rail links, grousers, bulldozer blades, end bits and fabricated members can be resurfaced easily. This attachment is operated by a gear which is mounted in the chuck.



These tractor rollers and an idler were rebuilt at a speed of 30 in. per min. by UNIONMELT *welding.*

With both machines, the wheels can be tilted for rebuilding the flanges. It takes only 80 to 90 minutes to rebuild a D-8 track roller. Idlers take about three times as long.

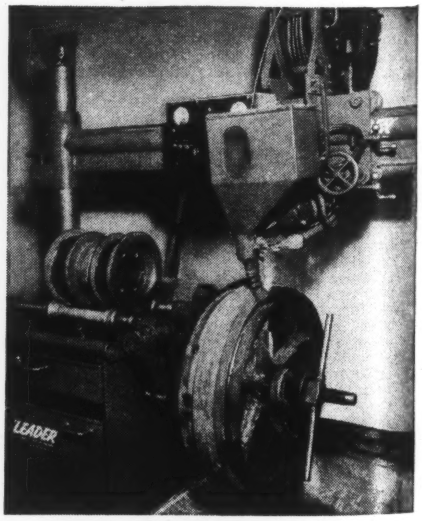
OXWELD 1928 rod is normally used in making these repairs. When wear is excessive, OXWELD 296 rod is sometimes used for the initial buildup which is then finished with OXWELD 1928 rod. For such resurfacing, use either Grade 80 or Grade 90 UNIONMELT welding compositions.

For some services, a finishing pass with a higher alloy tube rod is applied to produce a harder surface. While material of almost any hardness can be applied, one combining hardness and toughness lasts longer than one of higher hardness that tends to spall and chip. As deposited, OXWELD 1928 material has a hardness of about Rockwell C-25, but in service the working surfaces actually develop properties which cause them to outwear deposits that are substantially harder.

Advantages of UNIONMELT Build-up

UNIONMELT welded resurfacing is especially attractive with these automatic machines which readily permit deposit rates of 20 lbs. per hour. Savings in time and the advantages of a smooth uniform deposit justify the initial investment in automatic equipment. Important in these times is the conservation of metal realized with the process. The use of approximately *one hundred pounds of weld metal saves replacement of 2,000 to 3,000 pounds of new parts.*

LINDE's engineers and technicians will be glad to give further information about UNIONMELT welding. Telephone or write today.



UNIONMELT *welding head on "Leader" fixture rebuilds rollers and idlers. Rollers are welded on top of the machine, idlers at the side, and flat parts, depending on their size, can be welded on top of the machine or in the flat work attachment.*

LINDE AIR PRODUCTS COMPANY
A Division of Union Carbide and Carbon Corporation
30 East 42nd Street UCC New York 17, N. Y.
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In Canada: Dominion Oxygen Company, Limited, Toronto

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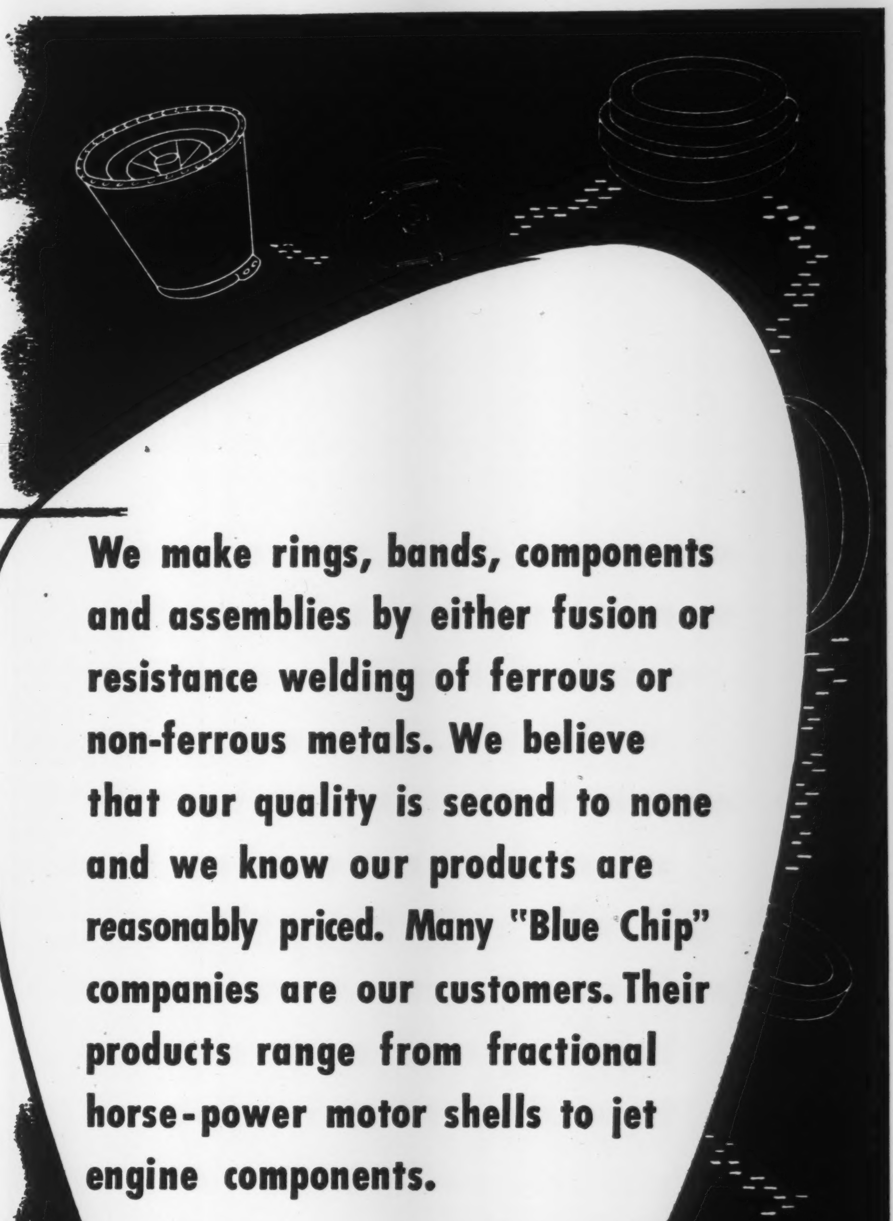
PRODUCTS



We make rings, bands, components and assemblies by either fusion or resistance welding of ferrous or non-ferrous metals. We believe that our quality is second to none and we know our products are reasonably priced. Many "Blue Chip" companies are our customers. Their products range from fractional horse-power motor shells to jet engine components.

What can we make for you?

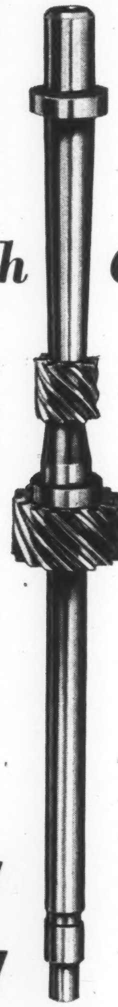
A company you'll like to deal with

THE AMERICAN WELDING &
MANUFACTURING CO. · WARREN, OHIO

LET US SEND YOU MORE FACTS OR
BETTER YET SEND US YOUR SPECIFICATIONS
FOR PROMPT QUOTATIONS

**Send for your copy
of our 20 page
illustrated catalog**

New Concepts in Fine-Pitch Gear Supply!

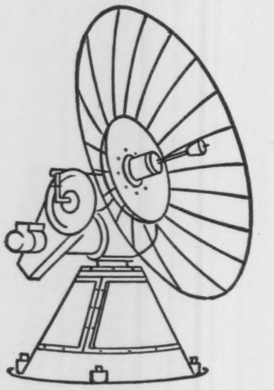


RYNEL

CUSTOM ENGINEERING

Rynel's complete range of facilities for fine-pitch gear production is your best answer to gear supply problems.

Custom-cutting of high-quality fine-pitch gears at minimum cost is Rynel's **sole** concern. Equipped with the finest modern machinery and a broad background of experience-training, Rynel is ready to fulfill **your** fine-pitch gear needs . . . in quality **and** quantity.



Rynel design engineering . . . production control from bar stock to finished gear . . . precision inspection . . . high volume supply . . . personalized air-lift service . . . all yours, when you specify Rynel fine-pitch gears.

Rynel supplies Precision FINE-PITCH GEARS for all major Electronics-Instruments-Communication Applications.

A Rynel Engineer will visit you the same day you call.

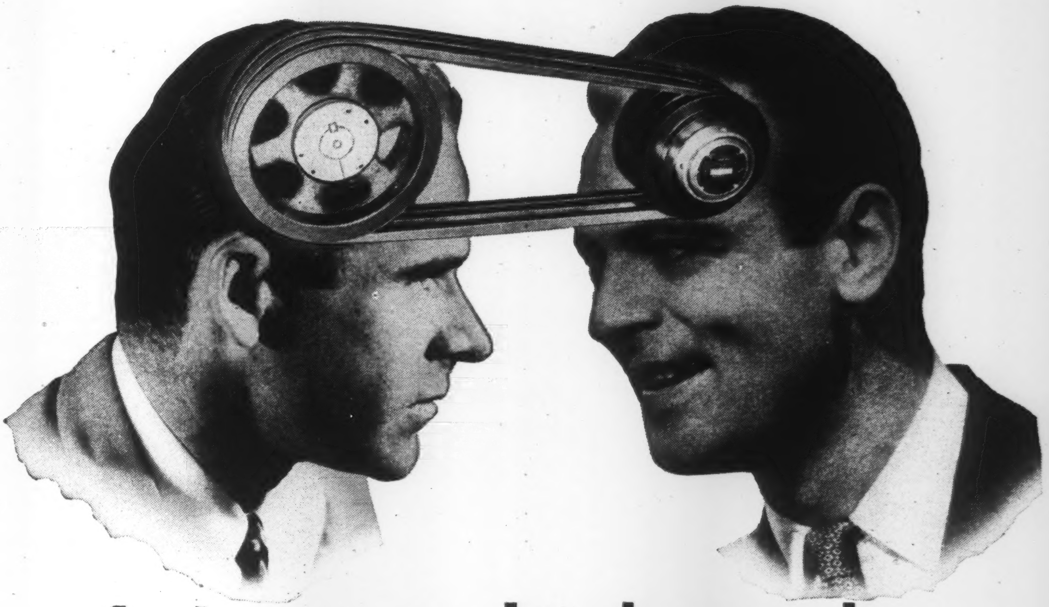
PHONE STERLING 4440

301 Miller Street • Sterling, Illinois

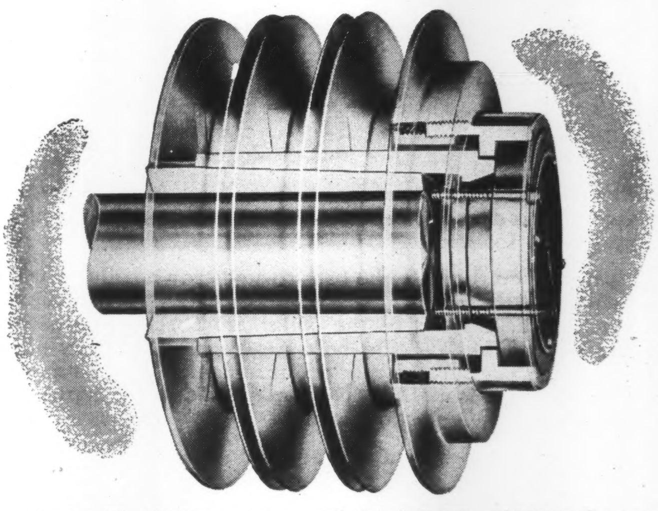
Chicago Office • 4730 Northwestern Avenue
Telephone Longbeach 1-7111

CORPORATION

Spur • Helical • Worm • Worm Gear • Internal
Segment • Sprocket • Ratchet • Straight Bevel



Let's get our heads together about speed control—and PROFIT!



American Adjustable-Speed Drives are available in A, B, C, Q, and R Section Grooves.

When the competition is tough—there's a lot of profit in that final extra production from every machine in a shop. And that extra production—that touch of gold—is what we'd like to talk over with you.

The American Adjustable-Speed line can add that touch of gold to your production . . . quickly, easily, inexpensively. YOU GET:

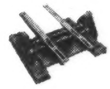
• Precision Speed Control • High Production at minimum capital and maintenance cost • Better quality control • Flexibility to meet variations in rated motor speeds or calculated speeds of belt drives

American's exclusive double-taper hub construction maintains speeds at your selected setting and long life of sheave and belts. Sleeves expand to lock flanges in position and the sheave to the shaft during operation . . . there's no chance for wear. Installation or removal is no problem . . . tapered bushings make American Adjustable-Speed Sheaves easy on and easy off the shaft.

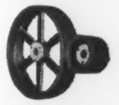
Get the profit story of the American Adjustable-Speed line and see how it can help you to more profit. You're not obligated when you clip and mail the coupon today.

Other Products

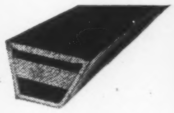
Speed Reducers and Overload Releases



Econ-O-Matic Motor Bases



Multiple-Groove Wedg-Tite Sheaves



Wedgbelts

Steel Split Pulleys

Hi-Torque Motor Pulleys

Conveyor Pulleys

Backstops

At the profit end of the machine

Power Transmission by
AMERICAN
PULLEY COMPANY

THE AMERICAN PULLEY COMPANY
4236 Wissahickon Ave., Philadelphia 29, Pa.

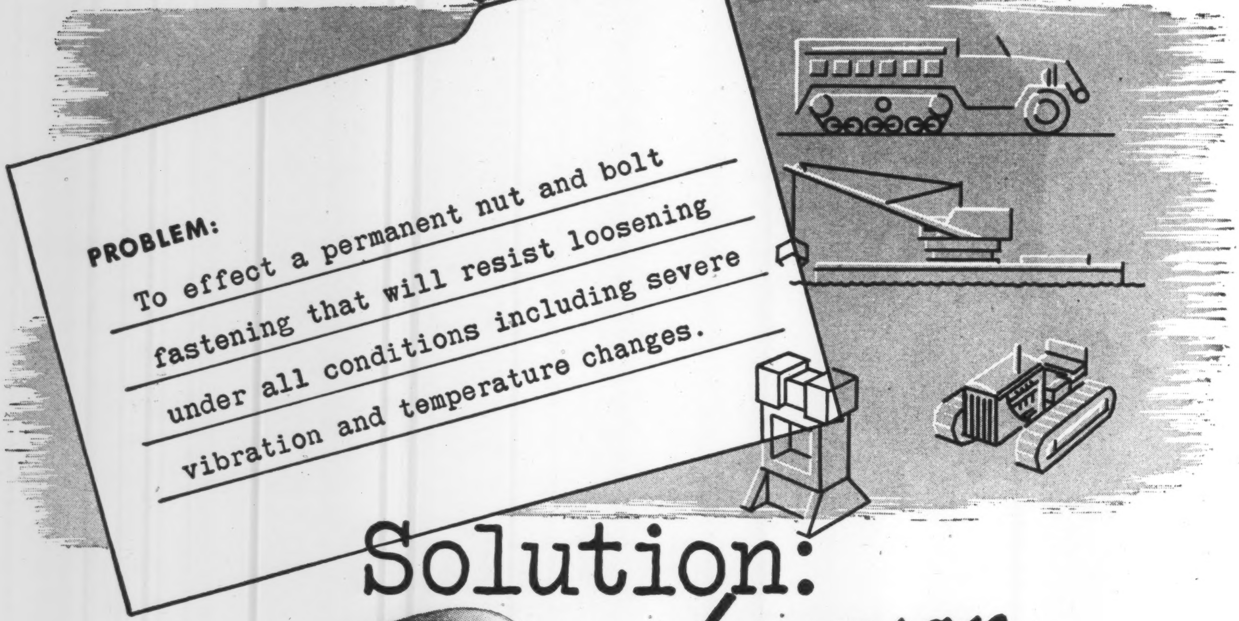
Gentlemen:

Please rush me your bulletin on the American Adjustable-Speed line.

*Name*____

*Address*______________________________________

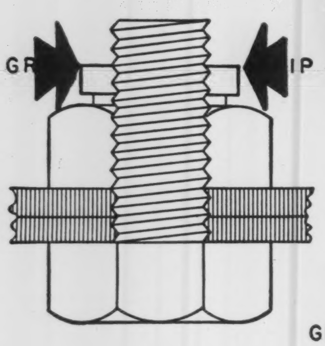
*City*________________________ *Zone*____ *State*________



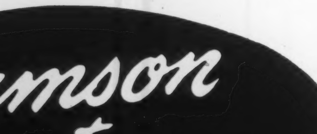
PROBLEM:

To effect a permanent nut and bolt fastening that will resist loosening under all conditions including severe vibration and temperature changes.

Solution: *Lamson* LOCK NUTS



U. S. PAT. NO. 2255286



Lamson Lock Nuts were designed for use where the going is rough and tough. Thus they are the ideal nuts for use where vibration is a factor . . . automotive equipment, construction machinery, railroad engines and cars and similar products.

Unlike many other lock nuts, the Lamson Lock Nut is a *one-piece all steel* nut that does not depend upon inserts or special methods of application for use.

As it is turned on the bolt, the heat-treated crown collar, slightly distorted from the round, grips the bolt firmly. When the nut is tightened the threads of the collar are forced against the "non-pressure flanks" of the bolt. Since the main body of the nut is exerting pressure on the "pressure flanks" a locking radial action results. Lamson Lock Nuts may be reused repeatedly without losing their locking action.

So, if you have a problem as stated above, consider Lamson Lock Nuts. They are the ideal solution from every standpoint.

Lamson + Sessions

The LAMSON & SESSIONS Co.
1971 West 85th St. • Cleveland 2, Ohio
Plants at Cleveland and Kent, Ohio • Birmingham • Chicago

The facilities of our company are at your disposal to assist you with any fastener problem.

Check the products below that interest you; tear off bottom of ad and send to us for complete information.

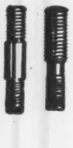
PLUG NUTS
Fasten metal parts efficiently from one side of the work.

PIPE PLUGS
Forged steel, heat-treated.

"1035" SET SCREWS
Cup point type, hardened and heat-treated.

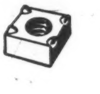
PLACE BOLTS
With "Built-in" spring action for positive locking.

LAMSON LOCK NUTS
Economical, vibration proof. Can be used repeatedly.

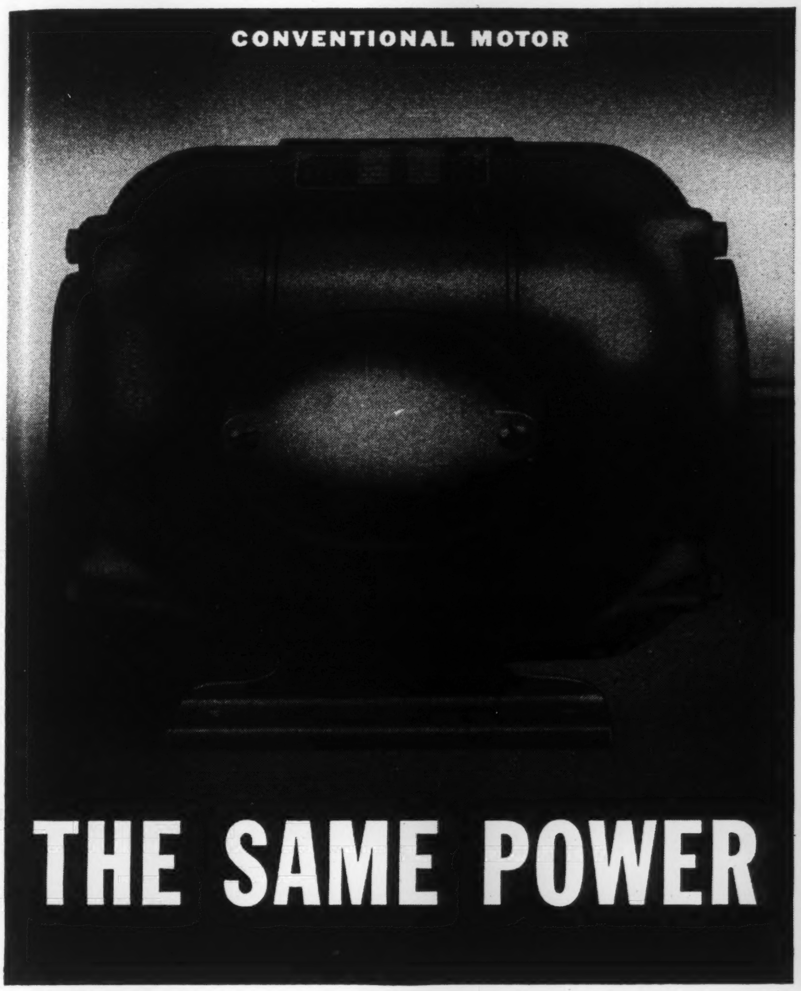


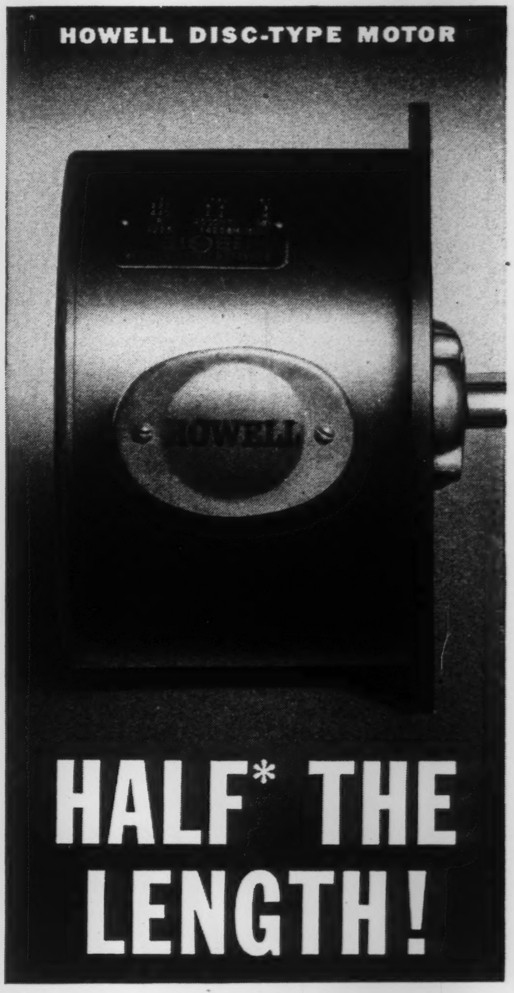
LOK-THREAD PRODUCTS
For positive locking and sealing.

DIAMOND LOCK SCREWS
Plastic insert locks threads. Can be reused.



WELD NUTS
For strong, always level welding.





* Depending on horsepower, reduction in length ranges from 41.7 to 50.5%!

Compact motor design offering wide range of sizes (from ¼ to 20 h.p.) and variety of electrical types presents positive advantages to machine designers and electric motor buyers!

Here's something really unusual in electric motor design! A motor-type that delivers the same power, has the same characteristics as conventional motors . . . yet its length has been *cut* by as much as *one half!* It's the Howell Disc-Type Motor!

The comparison above shows the drastically reduced length of the Disc-Type Motor as against a conventional motor of the *same horsepower*. The shorter length is achieved by flattening the end plates and moving the ball bearings back into the motor. *Every other feature of rugged, precision-built Howell Motors is retained.*

The Disc-Type Motor is available in your choice of horsepower, frame sizes, mountings, electrical characteristics; you may have open or totally enclosed types, single or polyphase, with integrally-mounted brakes if desired.

These space-saving motors have proved successful in dozens of main-drive and auxiliary applications where space is at a premium. They are particularly suitable for cranes, hoists and rapid traverse drives. Call the Howell representative in your city for expert assistance in applying Howell Disc-Type Motors to *your* machines. For a free technical bulletin giving specifications, clip and mail the coupon today.

WIDE RANGE OF SPECIFICATIONS

1. Sizes from ¼ to 20 h.p. at 1800 r.p.m. including intermittent hoist types. Corresponding ratings at other speeds also available.
2. Open or totally enclosed types.
3. Electrical characteristics—NEMA designs A, B, C and D, as well as elevator and torque motor types.
4. Foot or flange mountings.
5. Frame sizes A-56 to A-326.
6. Integrally-mounted brakes if desired.

HOWELL ELECTRIC MOTORS COMPANY
Howell, Michigan

Please send me a free copy of the technical bulletin on Howell Disc-Type Motors.

Name____________________

Firm____________________

Address____________________

City________________ Zone________

State____________________

HOWELL Red Band MOTORS

HOWELL ELECTRIC MOTORS CO.

HOWELL, MICHIGAN

PRECISION-BUILT MOTORS FOR INDUSTRY SINCE 1915

It "Takes the Pick" of Your Clothes

4 000
3 000
2 000
1 000
1 2 3 4
MON
TUES
WED
THURS
FRI
SAT
VR50
VEEDER-ROOT
1 2 3 4

Added Evidence that

Everyone Can Count on VEEDER-ROOT

Weavers know this as a Pick Counter, because it counts the picks, or trips of the shuttle across the loom as cloth is woven. And this is the newly modernized model of the original V-R 2-3 Convertible Counter. 4th counting unit is also available.

This is another V-R "first" in advancement of counter design for every field of industry. And it's more than likely that V-R can supply or design a counter that will count to *your* advantage. Find out. Write:

VEEDER-ROOT INCORPORATED
"The Name That Counts"
HARTFORD 2, CONNECTICUT
Chicago 6, Ill. • New York 19, N.Y. • Greenville, S.C.
Montreal 2, Canada • Dundee, Scotland
Offices and Agents in Principal Cities

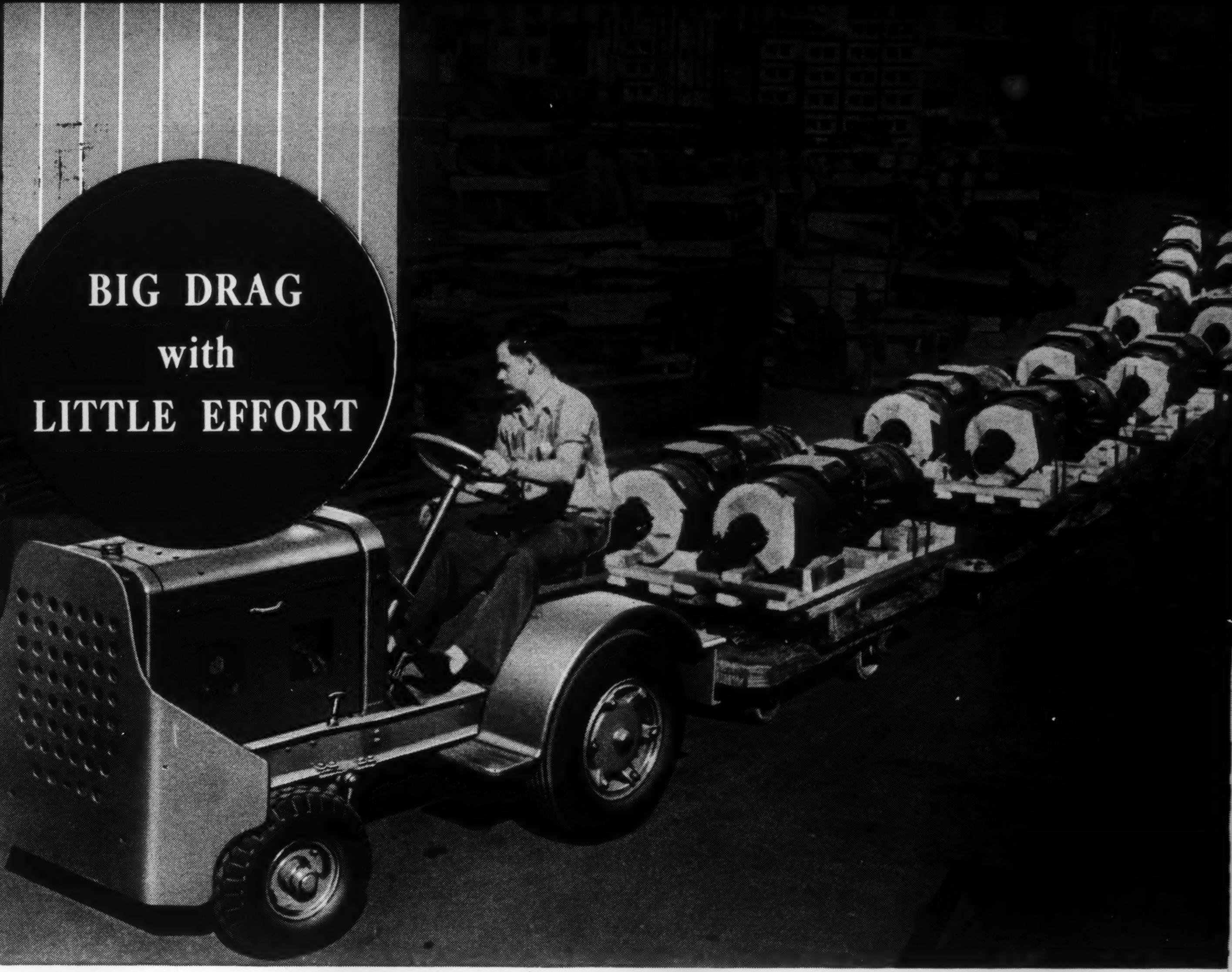
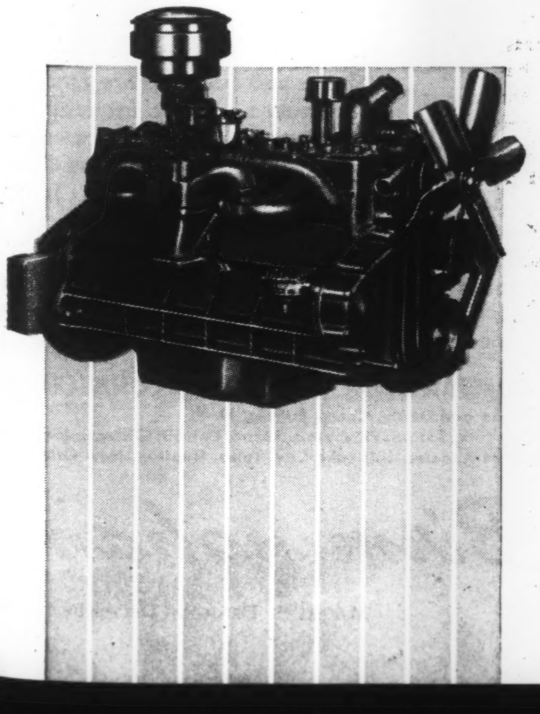


Photo courtesy Clark Equipment Company, Battle Creek, Michigan

Chrysler-powered Clarktor pulls more than two and a half times its own weight



There was a time when a load like this was considered too heavy for one trip. Today, pulling loads this big . . . and bigger . . . are a daily experience for towing tractors. Manufacturers depend almost completely upon mechanized plant transportation to put materials, parts and assemblies in the right places at the right times . . . to maintain the pace of modern-day mass production.

Here Chrysler Industrial Engine Model 6 teams up with a Clarktor 21 to move twenty-four 700-pound street car motors from production line to shipping dock. This is but another fine example of the workhorse-dependability of Chrysler High-speed and High-compression . . . of Chrysler-engineered Power at Work.

Chrysler offers a large number of options from which you can "custom-equip" industrial engines to *meet your own specifications.* Propane or natural gas-burning carburetors, updraft or downdraft carburetion, standard, fungus-treated or corrosion-resistant electrical systems, gyrol Fluid Coupling or Torque Converter . . . to name only a few.

Despite all these advantages, Chrysler Industrial Power is not expensive. Production-line methods adapted to specialized industrial engine building, provide a custom-built engine at mass-production prices.

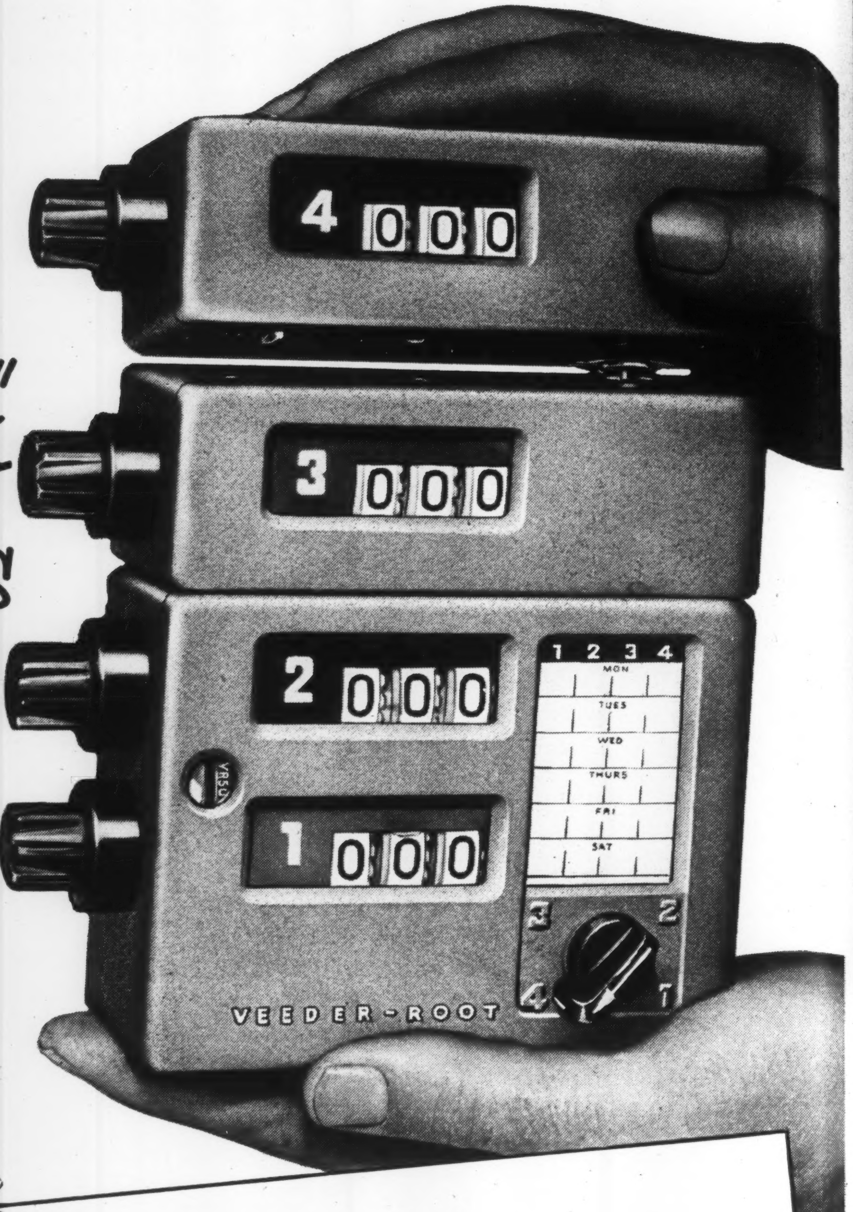
Chrysler Power can work for you, too. See the nearest Chrysler Industrial Engine Dealer. Let him recommend one of nine basic Chrysler Engines. If your problem is special, write: **Dept. 412 Industrial Engine Division, Chrysler Corporation, Trenton, Michigan.**

CHRYSLER

Industrial Engines

HORSEPOWER WITH A PEDIGREE

It "Takes the Pick" of Your Clothes



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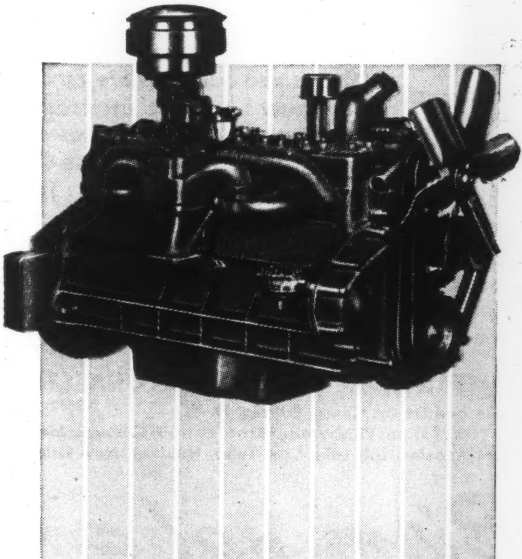
VEEDER-ROOT INCORPORATED
"The Name That Counts"
HARTFORD 2, CONNECTICUT
Chicago 6, Ill. • New York 19, N. Y. • Greenville, S. C.
Montreal 2, Canada • Dundee, Scotland
Offices and Agents in Principal Cities

BIG DRAG
with
LITTLE EFFORT

Photo courtesy Clark Equipment Company, Battle Creek, Michigan

Chrysler-powered Clarktor pulls more than two and a half times its own weight



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CHRYSLER
Industrial Engines

HORSEPOWER **WITH A PEDIGREE**

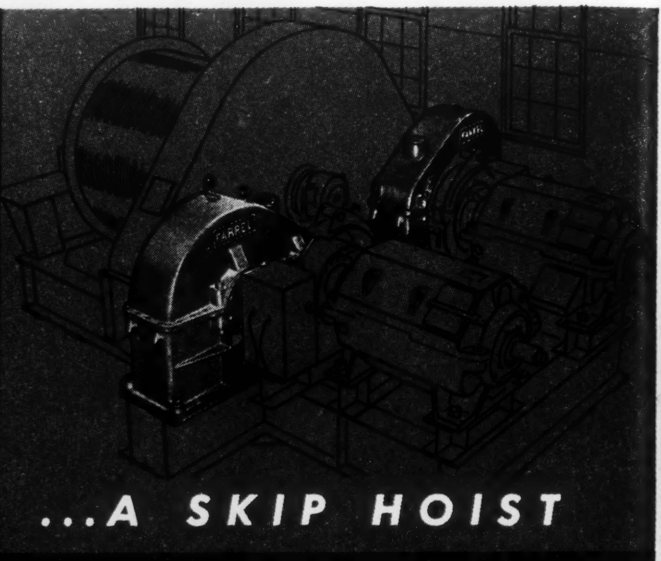
WHAT THE

Design Flexibility

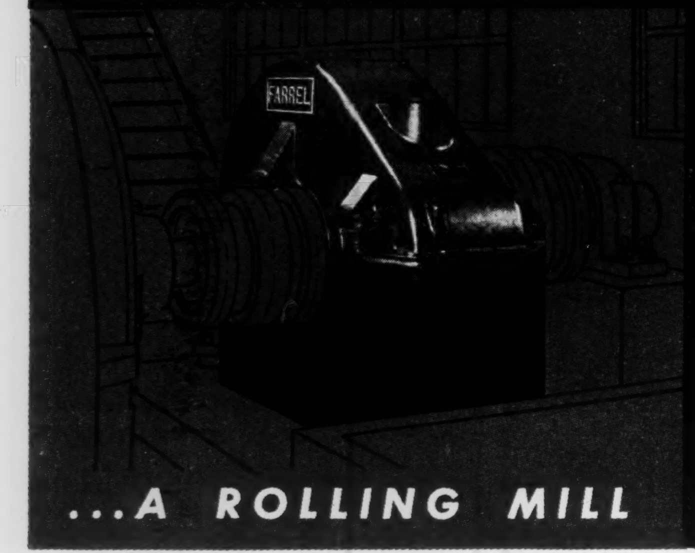
OF

FARREL® SPEED REDUCERS

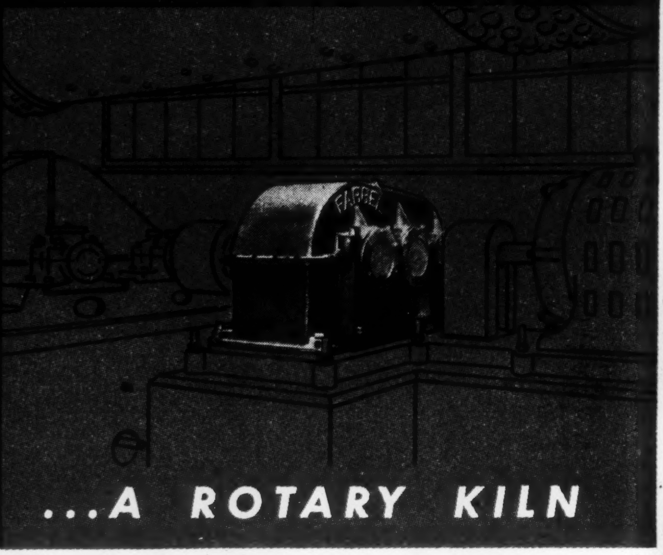
MEANS TO...



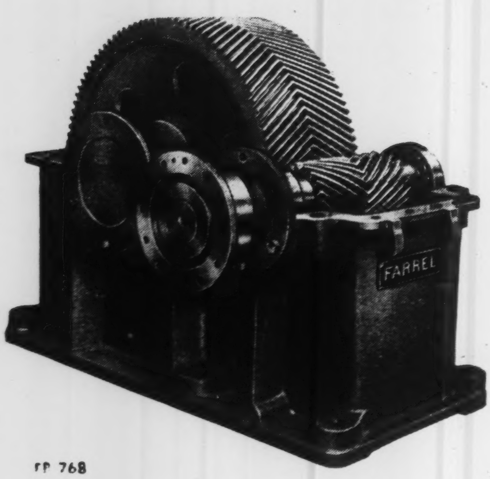
...A SKIP HOIST



...A ROLLING MILL



...A ROTARY KILN



FP 768

Design flexibility means the same thing in each of these applications: *a speed reducer that meets the drive requirements exactly.*

Farrel speed reducers, unlike most "standardized" products, are standard only in their principal features. They are adaptable in critical detail. Gears, shafts, bearings, and even some housing dimensions, can be proportioned to meet specific load, speed and service requirements. This flexibility has resulted in the solution of innumerable application problems.

In addition to this feature, Farrel speed reducers have a number of other advantages. The quiet, vibration-free performance of the herringbone gears results from extreme accuracy of tooth spacing, contour and helix angle . . . qualities inherent in the Farrel-Sykes method of gear generation. Precision manufacture and highest grade materials contribute to long gear life.

Shafts and bearings are factored to safeguard against interruption of vital processes. Gear cases are proportioned to withstand repeated heavy peak loads. Joints are sealed to prevent entrance of dirt.

Write for further details of these problem-solving units. Ask for a copy of Bulletin 449.

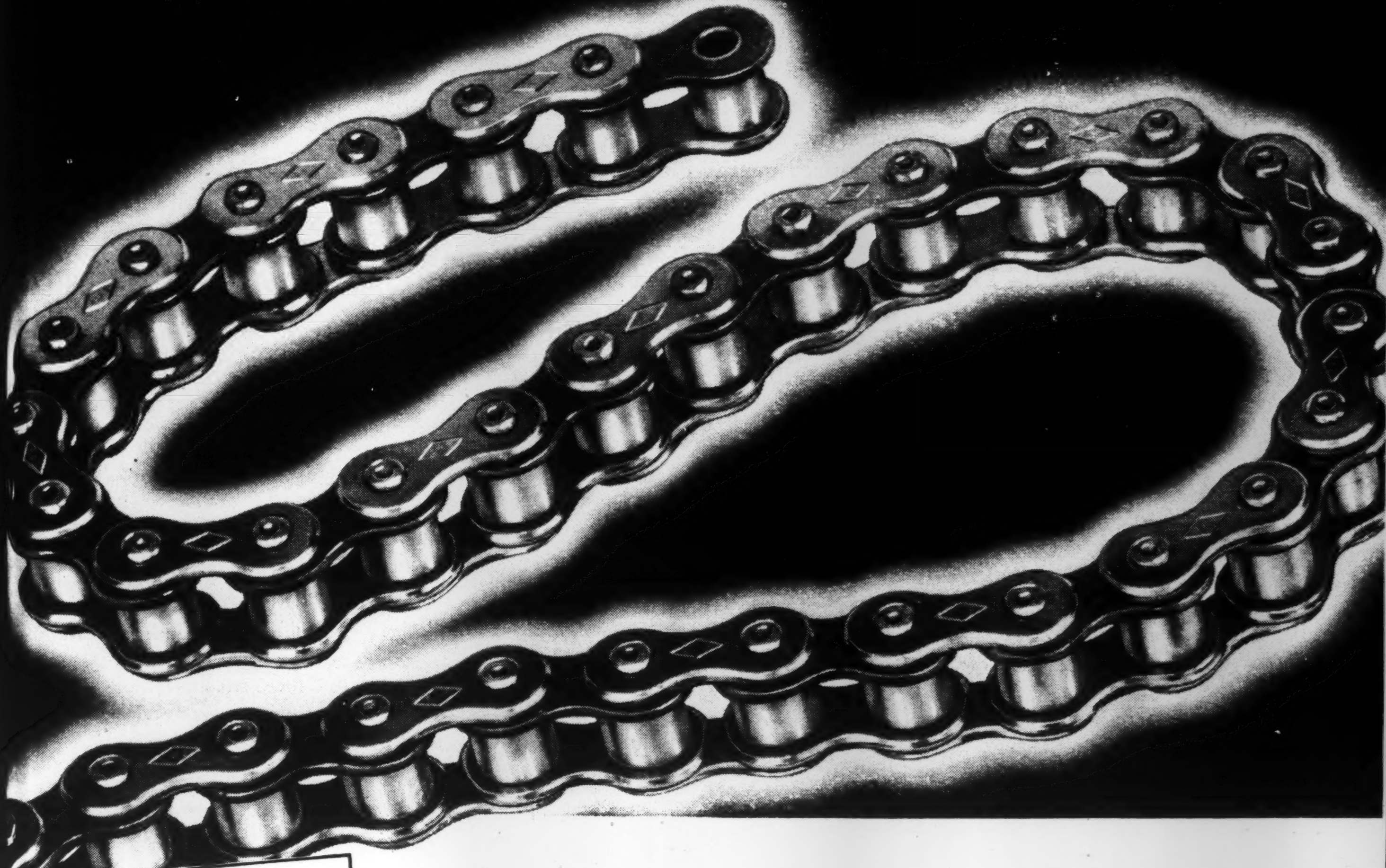
FARREL-BIRMINGHAM COMPANY, INC., ANSONIA, CONNECTICUT

Plants: Ansonia and Derby, Conn., Buffalo, N. Y.
Sales Offices: Ansonia, Buffalo, New York, Boston, Pittsburgh, Akron, Detroit, Chicago, Memphis, Minneapolis, Portland (Oregon), Los Angeles, Salt Lake City, Tulsa, Houston, New Orleans

Farrel-Birmingham®

DIAMOND

ROLLER CHAINS *of the highest quality*



An Important Diamond Advantage— Pitch Hole Preparation

Maximum rigidity of links insured by special pitch hole preparation for 100% effective bearing area of pin and bushing. Longer life, smoother operation.

●

For over 62 years Diamond Chains have demonstrated their many advantages in services of every kind and description. Proven performance is responsible for the high level position Diamond has been accorded.

Diamond Roller Chains are in such wide use because of their long record of strict uniformity of quality, smooth and quiet operation, great reserve strength, and long-life dependability. To many experienced production men, engineers and machinery designers, *Diamond* means Roller Chains of highest quality.

DIAMOND CHAIN COMPANY, Inc.
Dept. 435, 402 Kentucky Ave.,
Indianapolis 7, Ind.

Offices and Distributors in
All Principal Cities

DIAMOND ROLLER CHAINS

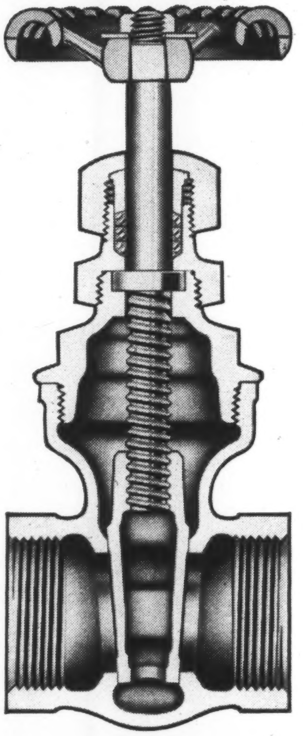
For quicker answers to piping problems

Go to your CRANE Catalog

Crane offers the world's most complete line of piping equipment. But suppose your design requires a certain brass gate valve of unusual ruggedness. How would you find it?

Simply reach for your Crane Catalog and turn to the listing of brass gate valves in the index—pages 13 to 21. A quick rundown of service recommendations shows that No. 437 on page 17 is the valve you're after. And right there are all the facts you need—sizes, dimensions, pressure and temperature ratings, plus complete design, material and construction details.

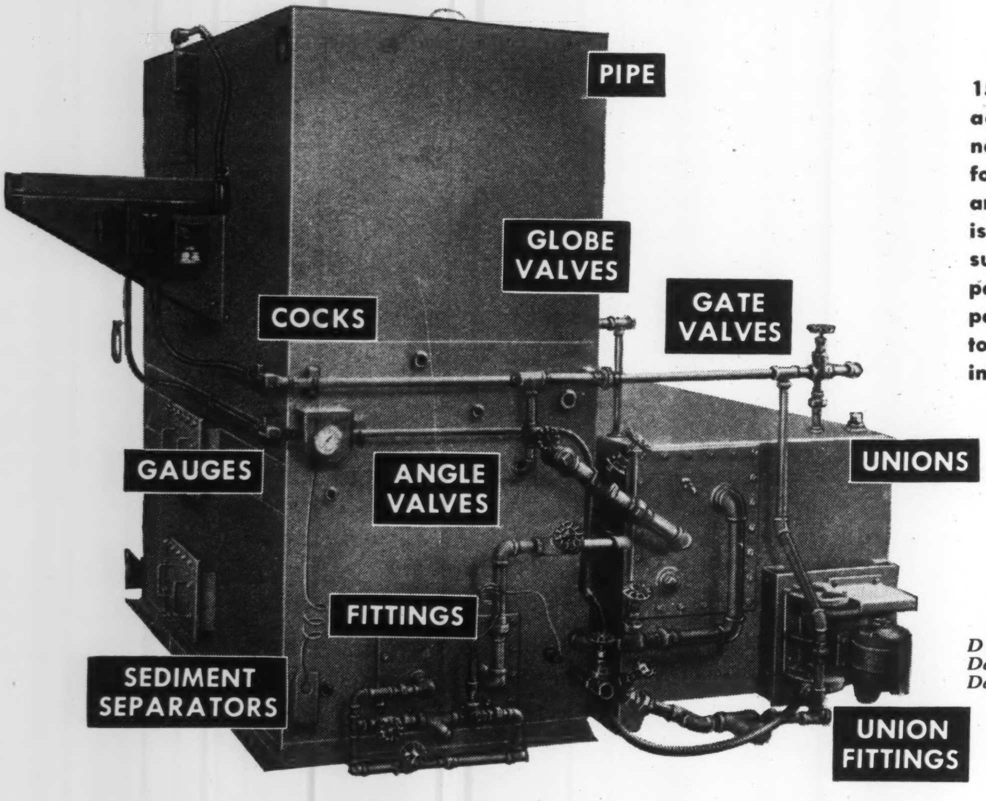
Yes, your Crane Catalog is a real time-saver when writing specs. But, more important, when you specify Crane piping equipment, you specify recognized quality that pays off in terms of customer acceptance and satisfaction through the years.



UNUSUALLY RUGGED

150-Pound Brass Gate Valve with accurately guided wedge disc, non-rising stem. Recommended for service on steam, water, oil and gas lines where extra strength is required. Tight stem seal assured by high quality stuffing box packing and gland; can be repacked under pressure. Sizes ¼ to 3-inch. Also available with rising stem, screwed or flanged ends.

● ***LOOK TO THE BROAD CRANE LINE FOR ALL YOUR PIPING EQUIPMENT NEEDS***



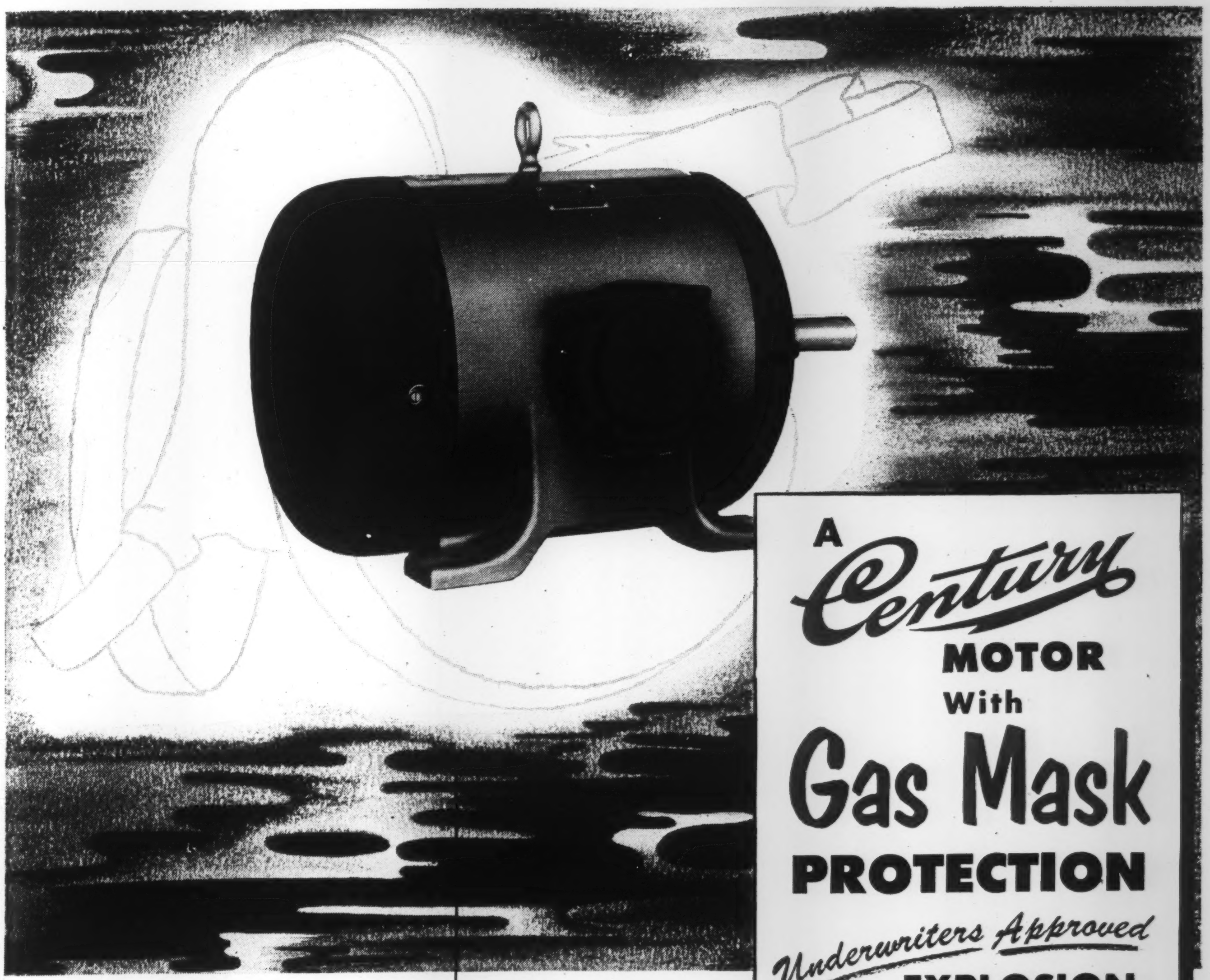
DETREX Steam-heated Gyro Degreaser by Detrex Corporation, Detroit, Michigan.

The Complete Crane Line Meets All Your Valve Needs. That's Why—
More Crane Valves Are Used Than Any Other Make!

CRANE VALVES

CRANE CO., *General Offices:* 836 S. Michigan Ave., Chicago 5, Illinois
Branches and Wholesalers Serving All Industrial Areas

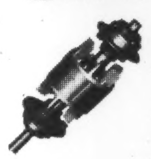
VALVES • FITTINGS • PIPE • PLUMBING • HEATING

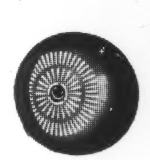


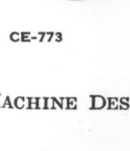
A Century MOTOR With Gas Mask PROTECTION

Underwriters Approved EXPLOSION PROOF MOTORS

Take a look at these Century Explosion Proof Motor features:







- Vital motor parts protected—sealed into inner frame.
- Motor can be reversed without changing direction of the fan—fan runs in either direction.
- Uniform ventilation surrounding outside of inner frame.
- Smooth, straight-through ventilating passages.
- Winding electrically insulated 6 different ways.
- Unusually free from vibration.
- Ball bearing housing keeps grease in—dirt out—lubricated for several years' normal service, with grease plugs for additional lubrication, if necessary.
- Easy-to-remove fan guard is held securely in place with two screws.
- Smooth exterior surface is easy to clean.
- Cast iron frame with integrally cast feet resists rust and corrosion—even when mounted in places where processed materials may contact the feet.
- Rugged construction gives generous safety factor for rough handling.

CE-773

Your property and employees are protected, because this Century Explosion Proof motor is totally enclosed—sealed to prevent a motor spark from causing an explosion.

Class I, groups C and D are used in atmospheres containing flammable gases or vapors: Ethyl ether vapors, gasoline, petroleum, napthha, alcohols, acetone, lacquer solvent vapors and natural gas.

Class II, groups E, F and G are used in atmospheres containing combustible dusts: Metal dust, carbon black, coal or coke dust and grain dusts.

Naturally, corrosive or abrasive materials in the air are also sealed out of the vital parts.

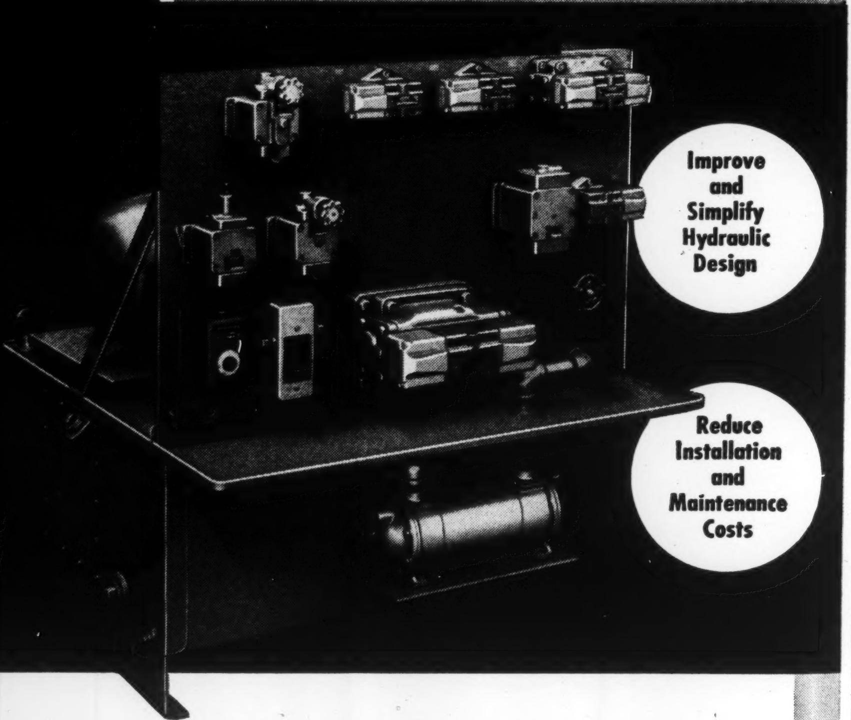
For your protection specify Century motors on the equipment you design. Century Engineers are always ready to work with you . . . to assist you in selecting the motor which will enable you to get top performance from your machine. These engineers can give you complete information on Century's wide range of motors—from 1/8 to 400 horsepower.

Century C MOTORS

CENTURY ELECTRIC COMPANY
1806 Pine Street • St. Louis 3, Missouri
Offices and Stock Points in Principal Cities

It Takes MORE than a Collection of Parts

To Make A VICKERS CUSTOM BUILT POWER UNIT


Improve and Simplify Hydraulic Design
Reduce Installation and Maintenance Costs

A Vickers Custom Built Power Unit is much more than a collection of parts . . . just as the machines you build are more than the castings, shafting, gears, motors, etc. that go into them.

The Vickers Unit is designed and built with the "know-how" obtained during more than a quarter century of experience in practically every kind of hydraulic operation, plus a thorough understanding of your needs. It is built exactly to your individual requirements. All necessary pumps, valves, intermediate piping, oil reservoir, motors, controls, etc., are in one compact and self-contained "package". It includes all needed hydraulic accessories such as oil filters, air cleaners, oil level gauges, fittings, etc. Hydraulic connections may be grouped in a conveniently located manifold.

The result is simplification of hydraulic design and important savings in installation and maintenance costs. Vickers undivided responsibility for the entire hydraulic control system is another important advantage to both the machine builder and his customer. • Write for new Bulletin 52-45.

VICKERS Incorporated
DIVISION OF THE SPERRY CORPORATION
1430 OAKMAN BLVD. • DETROIT 32, MICH.

Application Engineering Offices:
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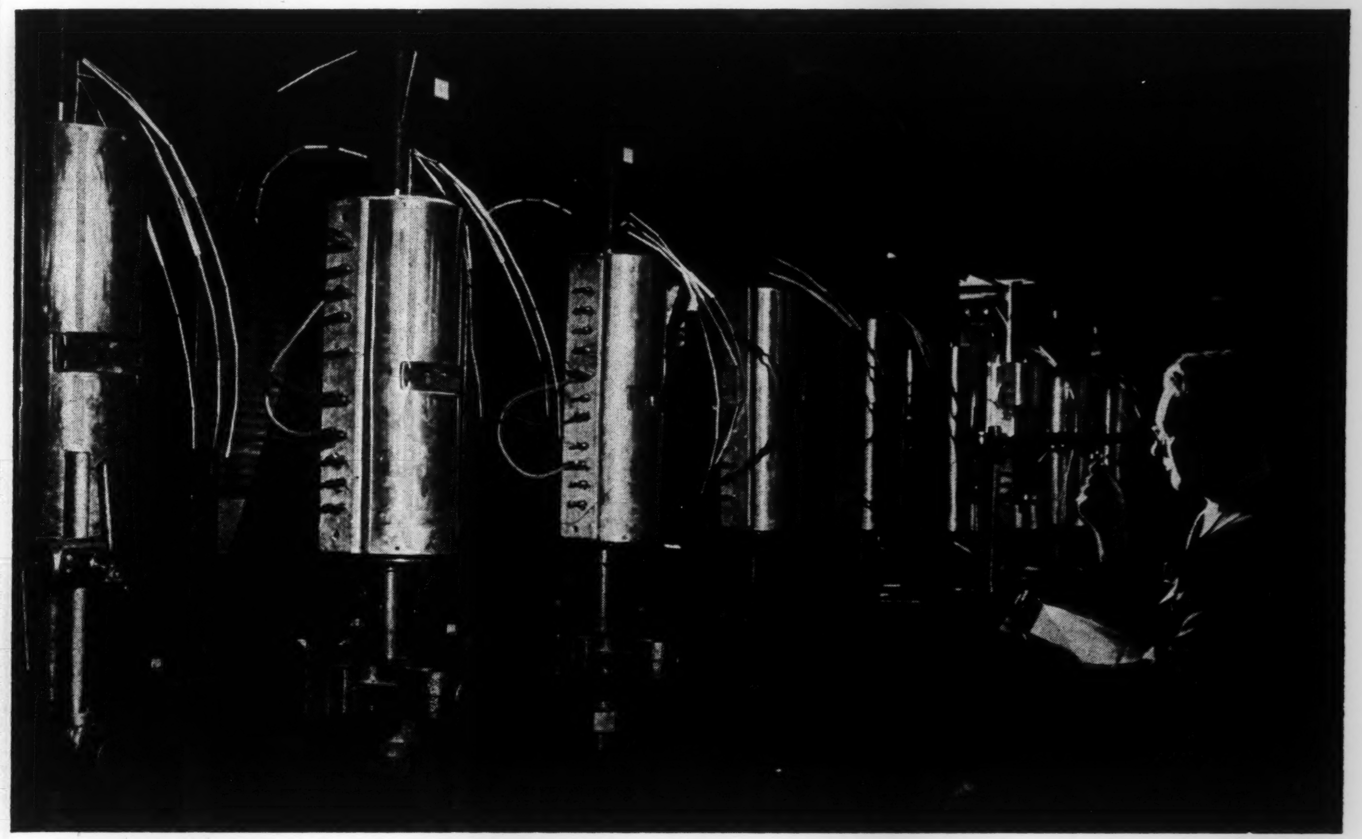
ENGINEERS AND BUILDERS OF OIL HYDRAULIC EQUIPMENT SINCE 1921



Where Metals Give Up Their Secrets

Suppose you want a metal to combat some particularly destructive set of service conditions.

Here's a man who can help you.

He's one of INCO's staff of engineering specialists and metallurgists. His primary responsibility is to determine how well a material qualifies for its intended use.

Often, he can find an answer to your problem among the metals and alloys he works with daily. He can tell you which of the INCO Nickel Alloys offers the most promising answer to your problem—and he can tell you just as frankly when a problem is outside the known scope of what the INCO Nickel Alloys can do.

Suppose, for example, you were caught in a predicament where you had to find a corrosion-resisting material with greater strength and hardness than you can get even in Monel®. He can name you an age-hardenable alloy that has the same excellent resistance as Monel *plus* mechanical properties you would expect to get only in a heat-treated alloy steel. Non-magnetic, too, down to −150° F. below zero. It is "K"® Monel, one of the INCO Nickel Alloys.

Maybe high temperatures complicate your problem. In that case he would study the service conditions and weigh out all the possible answers to your problem. Inconel "X"® is just one of a number of heat-resisting INCO Nickel Alloys that include Inconel®, the Nimonics, and the new Incoloy® — each one with different characteristics that make it best suited for different types of high temperature problems.

Remember this man. He can tell you where nickel alloys may safely be used to replace others containing even more critical metals. He can save you a lot of trial-and-error experimentation.

If you are wrestling with any problem that involves metals, let him lend a hand. There's no charge, no obligation. If one of the INCO Nickel Alloys cannot solve your problem, he may be able to recommend another metal that will. A note to "Technical Service" at this address will receive prompt attention:

THE INTERNATIONAL NICKEL COMPANY, INC.
67 Wall Street, New York 5, N. Y.

Inco Nickel Alloys

MONEL® • "R"® MONEL • "K"® MONEL • "KR"® MONEL "S"® MONEL • NICKEL
LOW CARBON NICKEL • DURANICKEL® • INCONEL® • INCONEL "X"® • INCOLOY® • NIMONICS®

Jenny doesn't live here any more!

YES, in the modern coal mine there's no room for Jenny. Today her job is done by powerful electric locomotives capable of pulling 50 times the load Jenny used to haul to the mine surface.

As a matter of fact, in the modern mine even the traditional pick and shovel are as out-of-place as Jenny herself! More than 90% of *bituminous* coal is now mechanically cut, and over 70% is mechanically loaded. Result: more economical coal to light the way, fuel the fires, power the progress of America.

But, basically, what caused Jenny to disappear? What's behind American industry's evermore efficient machines that turn out goods at lower cost—thus making them available to more people? One word tells the story—COMPETITION.

In the coal industry there are 5,000 privately managed coal companies competing with one another and all competing in the market with other fuels. When one coal company develops more efficient mining methods, the rest can keep pace only by striving to improve even further. No wonder that with his modern machines, developed through competition, the American miner's daily output is 4 to 24 times that of any miner in Europe or Asia—most of whom work in government-controlled coal industries.

Just as competition spurs *you* on to trying harder—it's competition that goads the individual company to deliver products that will outsell others. And it's competition that keeps a whole industry on its toes, cutting distribution costs, opening up new outlets, and delivering better products.

Competition—not government control—has already made America the most productive nation on earth. Competition—not regimentation—points the way to ever greater plenty for all of us.

★ ★ ★

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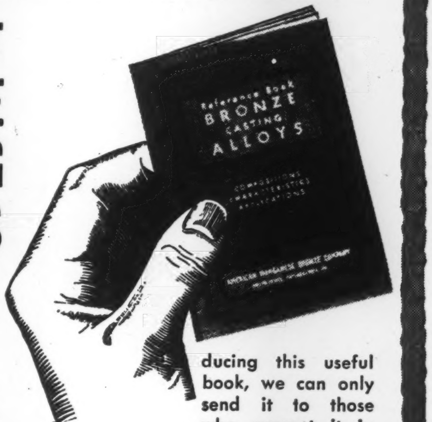
THE COMPETITIVE SYSTEM DELIVERS THE MOST TO THE GREATEST NUMBER OF PEOPLE

THIS BOOK . . . will answer all your BRONZE CASTING PROBLEMS

. . . *and it's* FREE



A 46-page, flat-opening, flexible-bound Reference Book that should be in the hands of every Engineer who specifies or uses Bronzes. Due to the cost of preparing and producing this useful book, we can only send it to those who request it in writing on their business letterheads — and remember, there's over 43 years "specialized experience" in casting Bronzes behind us.

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Write for the name of the BROWNING distributor near you

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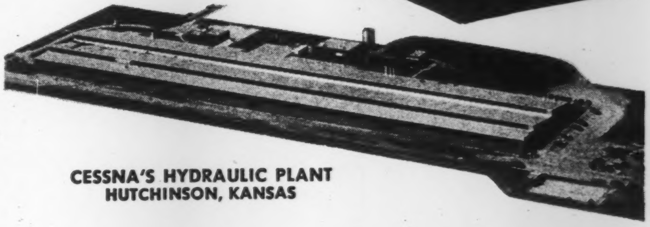
Cessna

IS A FAST DEPENDABLE SOURCE FOR PRECISION-BUILT HYDRAULIC UNITS IN QUANTITY

A specialist in hydraulics, Cessna is geared to save you time and money in quantity production of hydraulic units.

Here you'll find the skill, experience and plant facilities to produce a single component or a complete hydraulic unit of the highest quality.



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Our "Flying" Sales Engineers are always ready to work with you in the development of hydraulic units for your equipment. Wire or write, today.

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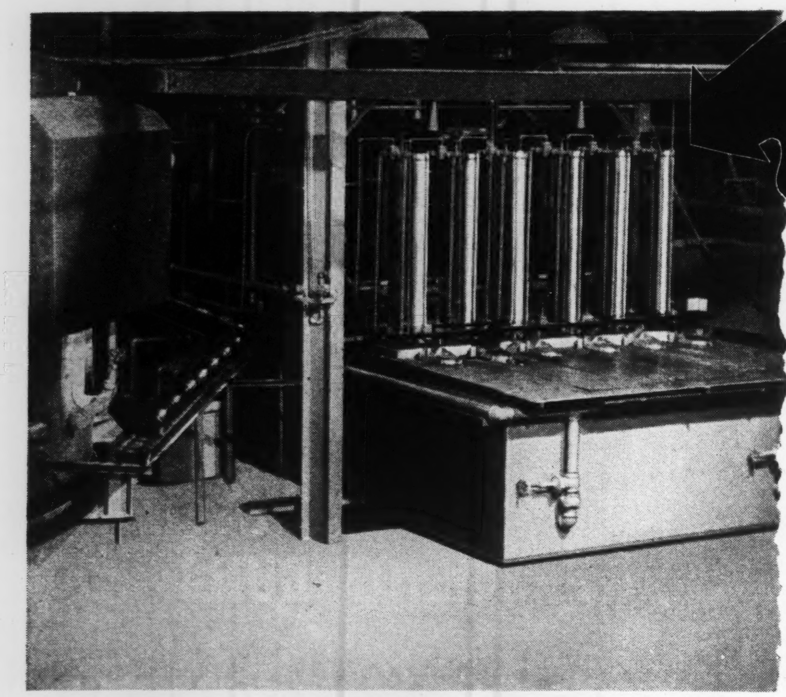


Quench Dipping with NOPAK Cylinders

Expedites Heat Treating Cycle

At the Gas Machinery Company, Cleveland, Ohio, work-pieces are conveyed from the heat treating furnaces into wire baskets which are then immersed into a quenching bath by a series of NOPAK Cylinders mounted vertically above the quenching tank. After quenching, the baskets are lifted out of the tank by the cylinders, and the parts are transferred to another conveyor, with the aid of another NOPAK Cylinder, for further processing.

This installation is typical of the many materials-handling operations in which NOPAK Valves and Cylinders are used. For others see the NOPAK Application Manual.

View of Heat Treating Department, at Gas Machinery Company, shows NOPAK Cylinders which dip baskets of parts into quenching tanks.

GALLAND-HENNING MANUFACTURING CO.

2752 SOUTH 31ST STREET • MILWAUKEE 46, WISCONSIN

Refer to Sweets File for Product Designers or write for Bulletin SW-1

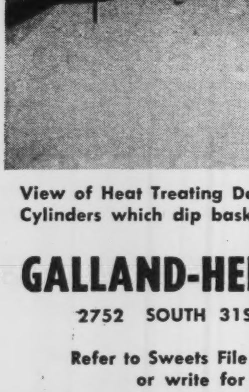
Representatives in Principal Cities

NOPAK

VALVES AND CYLINDERS

DESIGNED for AIR and HYDRAULIC SERVICE

A 7283-½-H



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Everything You Want in a Size 2 Magnetic Control

DUAL VOLTAGE COILS regularly furnished at no extra cost, single or polyphase, save time, reduce coil inventory.

PLASKON ALKYD ARC-BOX, most arc-resistant material available . . . fungus proof.

SPECIAL SILVER CONTACTS of high conductivity and superior arc-quenching properties.

PROVISION FOR ADDING CIRCUITS . . . Furnas Switchlets, each with normally open and normally closed contacts, may be easily attached by the user for auxiliary circuits.

RUGGED CONSTRUCTION of all parts for long life and trouble-free service . . . Direct acting solenoid type magnet and contact mechanism.

EASY TO CONNECT . . . Shallow case for good visibility; pressure type terminals are right out in front.

EASY ACCESS TO PARTS. Leads need not be removed to replace contacts . . . Coils can be quickly changed.

NEW #2 SERIES

Includes starters, contactors, reversing starters and reversing switches... with or without built-in push-buttons or selector switches. This series is available as open type, in general purpose cases or water-tight and dust-tight cast aluminum alloy enclosures.

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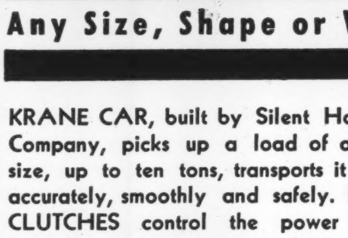
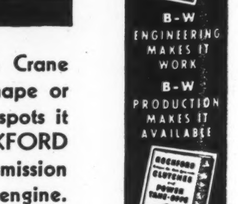
FURNAS *Electric* MOTOR CONTROLS

1045 McKee St., Batavia, Illinois

Lifts, Carries and Places





Any Size, Shape or Weight

KRANE CAR, built by Silent Hoist & Crane Company, picks up a load of any shape or size, up to ten tons, transports it and spots it accurately, smoothly and safely. ROCKFORD CLUTCHES control the power transmission from its one-man-operated single engine. Let ROCKFORD clutch engineers help with your power control problems.

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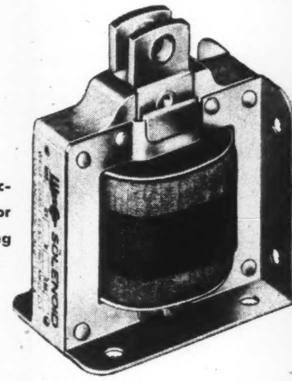


Vertical or Horizontal Mounting

Plunger Connections Bushed For Smooth Bearing Surfaces

Precision Designed For Long Life, Efficient Operation, And Compactness

Coils Easily Replaceable

These Solenoids incorporate Transformer Grade Silicon Iron, Stainless Steel Plunger Guides, Coils of Best Insulated Magnet Wire and Varnish.

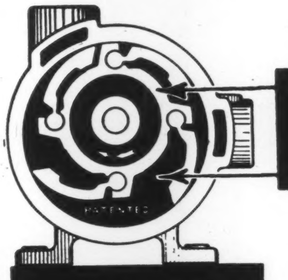
Our engineers are ready to solve your particular design or application problem.

Write for new 200 series AC Solenoid brochure.

DEPENDABLE **WesCo** PRODUCTS SINCE 1927

WEST COAST ELECTRICAL MFG. CORP.
CENTURY & MAIN ST. LOS ANGELES 3, CALIF.

LEIMAN AIR PUMPS give you *Greater Capacity!*



SMALLER PISTONS
provide
LARGER AIR SPACE

HINGED WINGS
take up their own wear

Compare this cross-section of a Leiman Air Pump with any other rotary air pump. It is working air space that counts—and Leiman provides 2 to 3 times more area, per size and weight of pump.

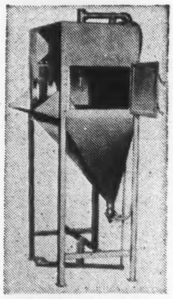
Handle your pressure, vacuum or suction jobs with much smaller Leiman Air Pumps. Save weight and space—have fewer moving parts—no springs, gaskets or packing—no tips to renew—nothing to give trouble.

What is your air application? Send us details. Leiman engineers offer over 60 years' experience with thousands of air applications. **Catalog and Application Data on request.**

For Pumps—write DEPT. A

Metal Cleaning and Finishing without acids or scratch brushes

LEIMAN SANDBLASTS

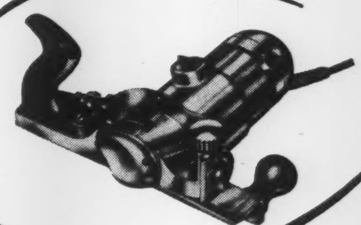


Fast, low-cost, safe, uniform way to clean scaly, rusty, rough surfaces—prepare for plating and finishing—stencil letters and designs—more rapid matte or satin finishes. Use unskilled help.

For Sandblasts—write DEPT. B

LEIMAN BROS., INC. 265 Christie St., Newark 5, N. J.

With this camera STANLEY vastly improved its electric plane



The solution to many design improvement problems lies hidden in parts moving too fast to see.

Stanley Works engineers had just such a problem with an electric plane—and found the answer with the aid of the Kodak High Speed Camera. When the motion was seen slowed down as much as 200 times, required design changes were readily apparent—changes which resulted in tremendously improved operation.

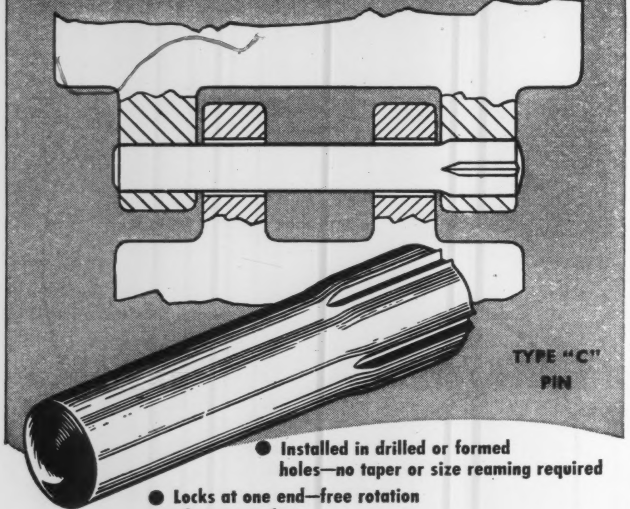
You can study countless problems of high speed mechanical motion and fluid flow with this single, complete unit. Taking up to 3200 pictures a second, it puts the visual facts you need on 16mm film for study whenever you wish. A new attachment permits simultaneous recording of oscillograph traces and physical action, if electrical aspects are important.

See for yourself how others have used this instrument to stretch a second of time to three minutes. Just send for your copy of the booklet, "Magnifying Time." Write to Eastman Kodak Company, Industrial Photographic Division, Rochester 4, N. Y.

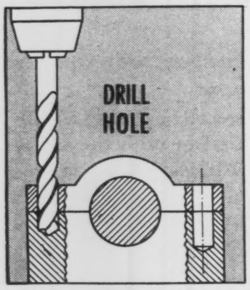
the Kodak *HIGH SPEED* Camera

Kodak

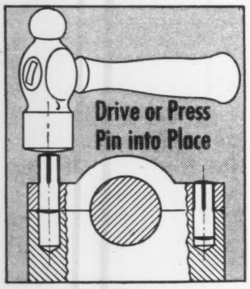
fast... low cost HINGE, LINKAGE or PIVOT assembly with DRIV-LOK PINS

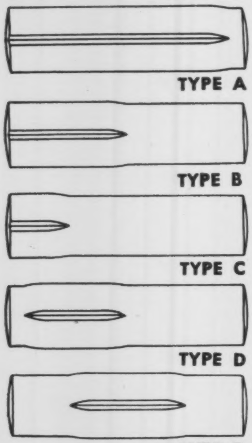


- Installed in drilled or formed holes—no taper or size reaming required
- Locks at one end—free rotation along rest of pin
- Vibration and shock-proof
- Low cost



2 EASY STEPS





Reduce costs and speed assembly of hinges, linkages or pivoted members by using DRIV-LOK Pins—the Pins that lock themselves securely by being driven or forced into the hole. Grooved at one end for positive anchorage, Type "C" Pins (illustrated above) permit free rotation of parts around the ungrooved portion.

DRIV-LOK Pins are available in many types—in carbon steel, stainless, alloy and brass; diameters from 3/64" to 1/2"; can be heat treated or plated to your specifications.

Write for Catalog and samples, giving nature of your fastening problem.

DRIV-LOK PIN COMPANY
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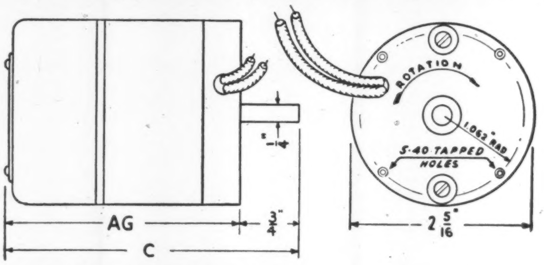
MANUFACTURERS OF ELECTRICAL PRODUCTS

Special Design Motors

Example: type LD3 (illustrated) for aircraft



SPECIFICATIONS - Type LD3

VOLTS	CYCLES	AMPS	DUTY	H.P.	R.P.M.
24	DC	2.2	Intermit.	1/95	3600
24	DC	3.75	Intermit.	1/35	3600
24	DC	1.5	Cont.	1/100	4000
24	DC	7.8	Intermit.	1/8	8500

12-32 volts D.C. — With or without electrical Governor — Ball Bearings — Details on Request.

Facilities and assistance are available for the development of special motors, shaded pole, series or D.C. to meet given requirements.

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A Yes—SEE ALCOA. Alcoa's finishing laboratories are continually improving and developing finishes for aluminum—painted, electroplated, anodized plus chemical and mechanical treatments. For the latest information, simply write on your company letterhead to:

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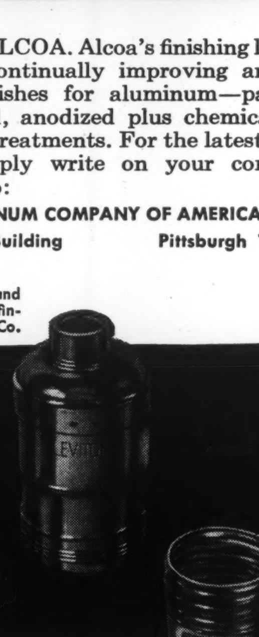
1975-M Gulf Building **Pittsburgh 19, Pa.**

Aluminum Shell Lamp Holder and Screw Shell manufactured and finished by Leviton Manufacturing Co.

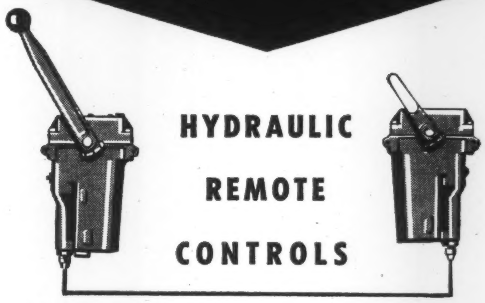


ALCOA

ALUMINUM COMPANY OF AMERICA

Sperry

INSTANT RESPONSE



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FOR
AVIATION, AUTOMOTIVE, RAILROAD, MARINE AND MACHINE TOOL INDUSTRIES

Every motion applied to the transmitter is duplicated INSTANTLY and POSITIVELY. The self-contained, single tube system is simple, reliable, easily installed.

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REPRESENTATIVES IN PRINCIPAL CITIES

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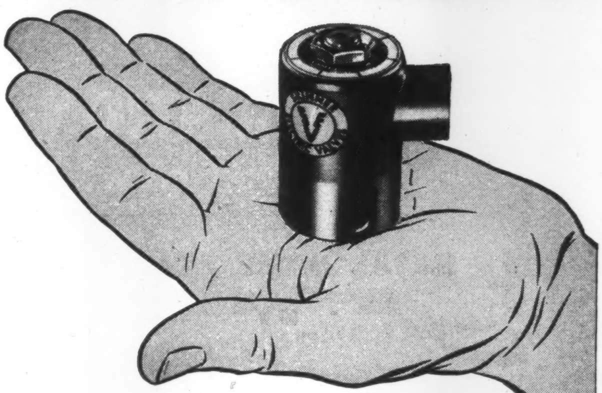


SKINNER STAINLESS STEEL SOLENOID VALVES

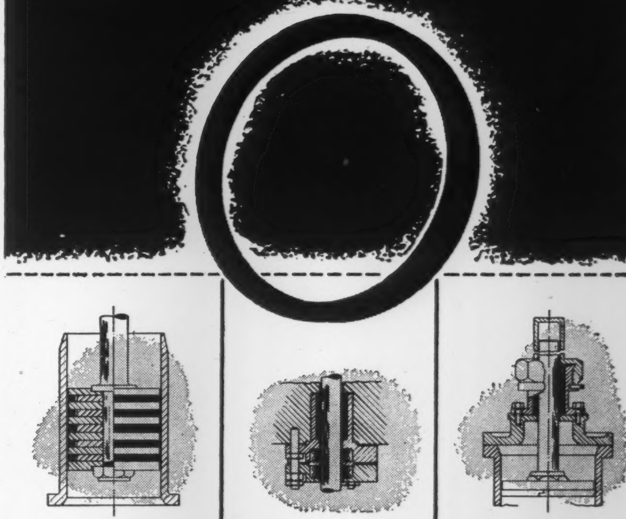
. . . Another case of "a good thing in a small package"! Users are amazed at the ruggedness and unusually large capacity of Skinner Valves—they're tiny but mighty, with a standard range for gaseous or liquid media from 5 to 250 p.s.i., and special from 5 to 850 p.s.i. Their soft insert seat prevents leakage and positive action is assured by spring loading. Skinner Valves may be used in any position, with pipe connections furnished to suit specifications. Power consumption is 10 watts max. Special coils for high humidity or high temperature applications can be supplied. Standard models are approved by Underwriters' Laboratories. *Write for Bulletin No. 501.*

SKINNER ELECTRIC VALVE DIV.
THE SKINNER CHUCK COMPANY
133 Belden Ave., Norwalk, Conn.

RETAIN PURITY *by installing* MORGANITE

SELF-LUBRICATING • NON-CONTAMINATING

PISTON RINGS



FOR OXYGEN COMPRESSORS AND OIL-FREE AIR COMPRESSORS

Morganite Advantages—Completely self lubricating, Morganite Piston Rings impart no taste or odor to contacting liquids or gases.

Operating Temperatures—Unaffected by heat or cold, maintain maximum efficiency over wide range. Eliminate "cold start" wear.

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on the board . . .

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ALUMINUM ALLOY

for High Strength and Light Weight

• The design is good, but the materials have to be just as good, too, in order for the product to operate efficiently in its end use. Many designers today are finding the specific qualities of FRONTIER 40-E Aluminum Alloy fit many parts of their products to a "T". Stress parts in planes, truck axles, axial fan rotors . . . all require free machineability, superior shock and corrosion resistance, and pressure tightness. FRONTIER 40-E has all these qualities, plus the extremely important fact that *test bar physical properties stay constant throughout large castings.* You'll benefit greatly by investigating the exact value of FRONTIER 40-E to your designs.

GET THIS HELPFUL ALLOY DATA FOR YOUR FILE . . . *today.* Write for your free copy.

Remember—if Aluminum can do it better —*FRONTIER 40-E ALUMINUM ALLOY* can do it *best!*

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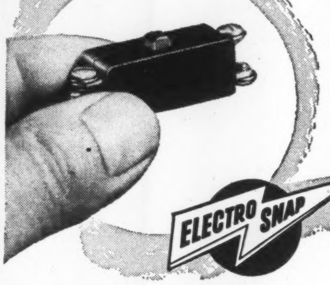
HERE'S a "NEW SWITCH" for YOUR DESIGNS



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**PRECISION
SNAP-ACTION
BASIC SWITCHES**

Tiny in size, tremendous in performance, Electro-Snap Basic Switches are compact and lightweight to fit inconspicuously into your designs. Built-in dependability and close-tolerance, *precision* construction assure long life and high quality service in products ranging from machinery controls to aircraft. Ideal for use as limit, control, interlock, safety, positioning or sequencing switches.

- Positive operation
- Accurate repeatability
- High electrical capacity
- Long contact life
- Many actuators and housings available to fit switches to wide range of applications

Write on your letterhead for information and sample Basic Switch—FREE

ELECTRO SNAP

ELECTRO-SNAP SWITCH & MFG. CO.
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STANDOUT IDENTIFICATION
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Spotlight your product with a sparkling metal name plate that reflects quality, lends distinction and assures permanent readability. Ask us to quote on name and instruction plates, dials, panels, etc. We also apply special finishes to aluminum products and parts including ANODIZING by the exclusive Alumilite process. Write today for information and quotations.

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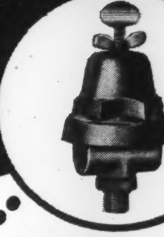
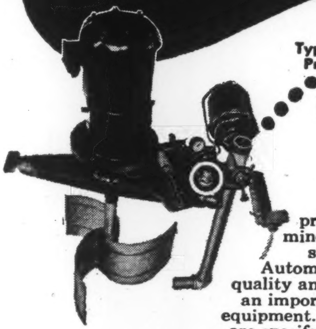
SUBSIDIARY OF DODGE MFG. CORPORATION, MISHAWAKA, IND.

CASH-ACME *Valves* DEMANDED BY INDUSTRY *Everywhere*



Type "A-31" Small Volume Pressure Reducing Valve



paper making equipment manufacturer specifies

CASH-ACME

Consistency is important in the pulp and paper industry. The proper density of the mixture determines the quality of the stock. The same holds true of CASH-ACME Automatic Valves . . . consistency of quality and performance make these valves an important addition to pulp and paper equipment. In fact, more and more industries are specifying CASH-ACME when there's a precision job of pressure reducing and regulating to be done. Write for free literature describing the part CASH-ACME Automatic Valves can play in the successful operation of your products.

CASH ACME SILENT SENTINEL *Automatic Valves*

A. W. CASH VALVE MANUFACTURING CORP.
6613 E. Wabash Avenue
Decatur, Illinois

IT'S 75 *to* 1

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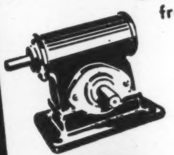

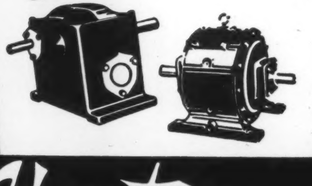

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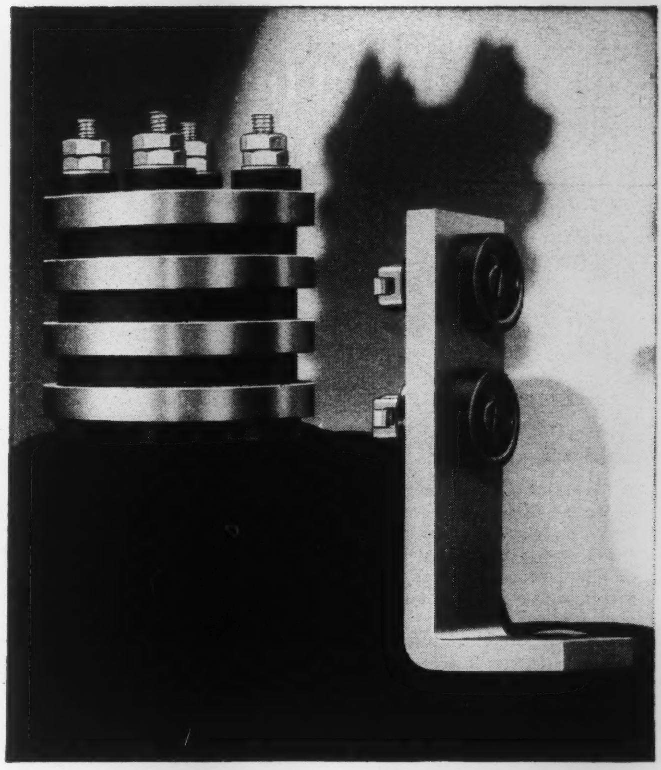

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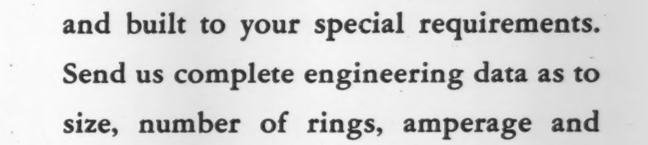

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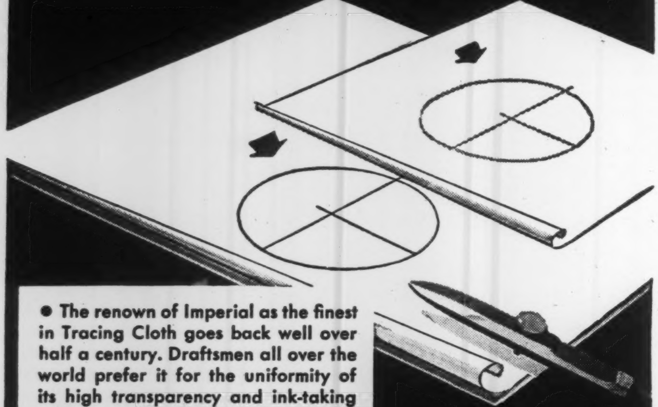

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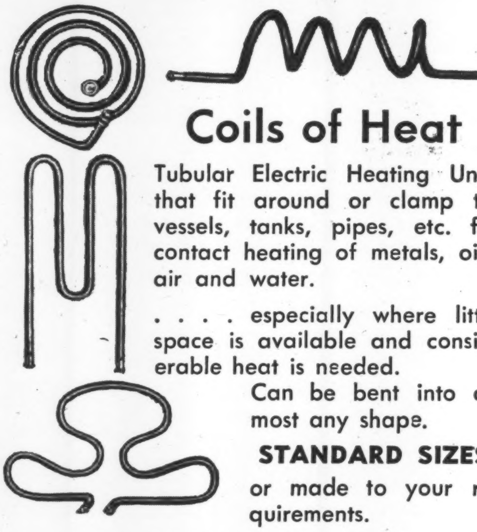

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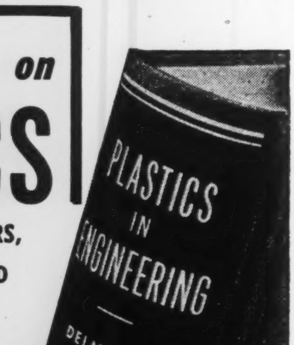

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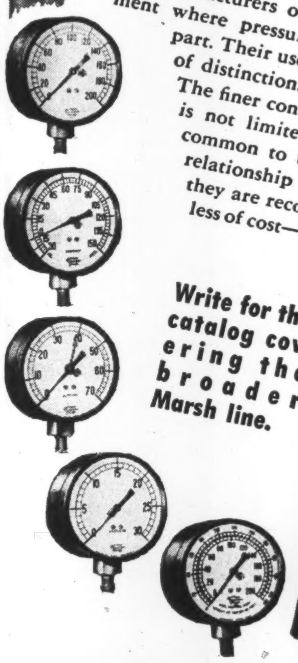

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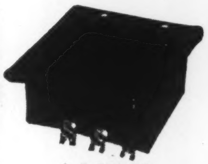

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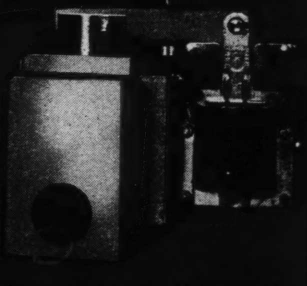

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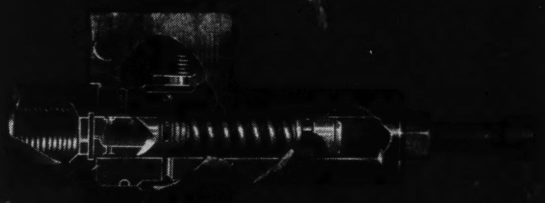

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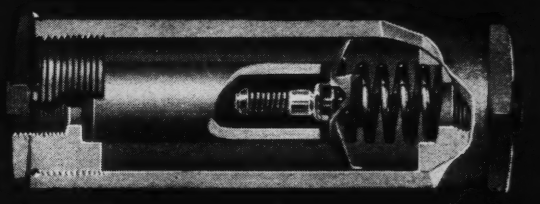

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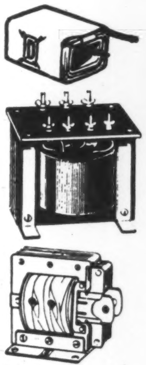

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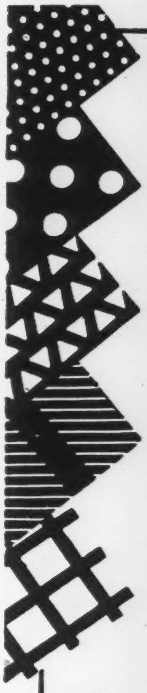

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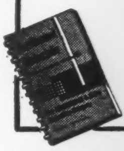

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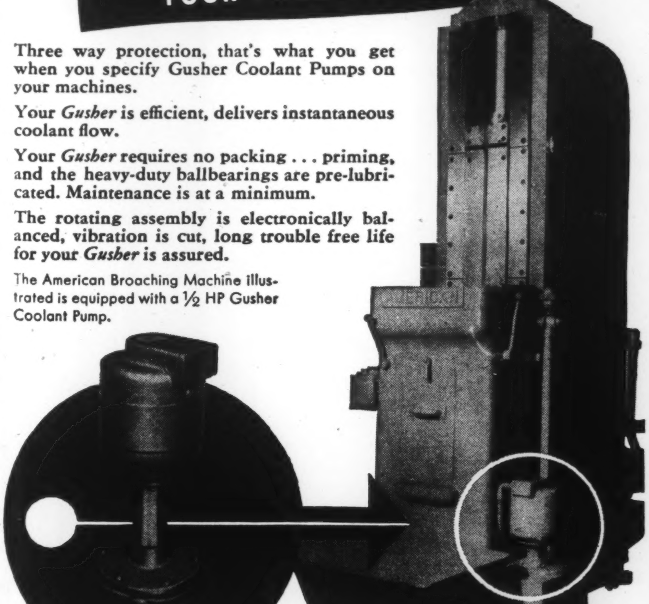

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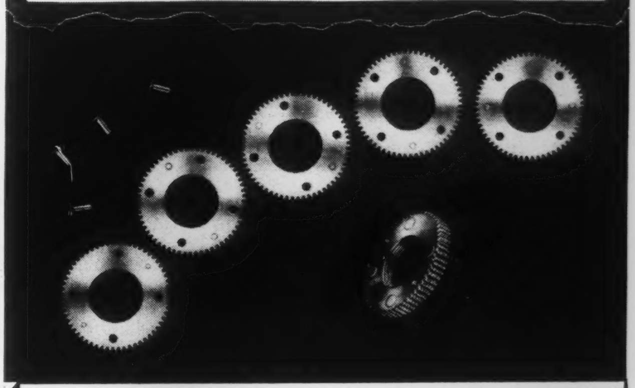

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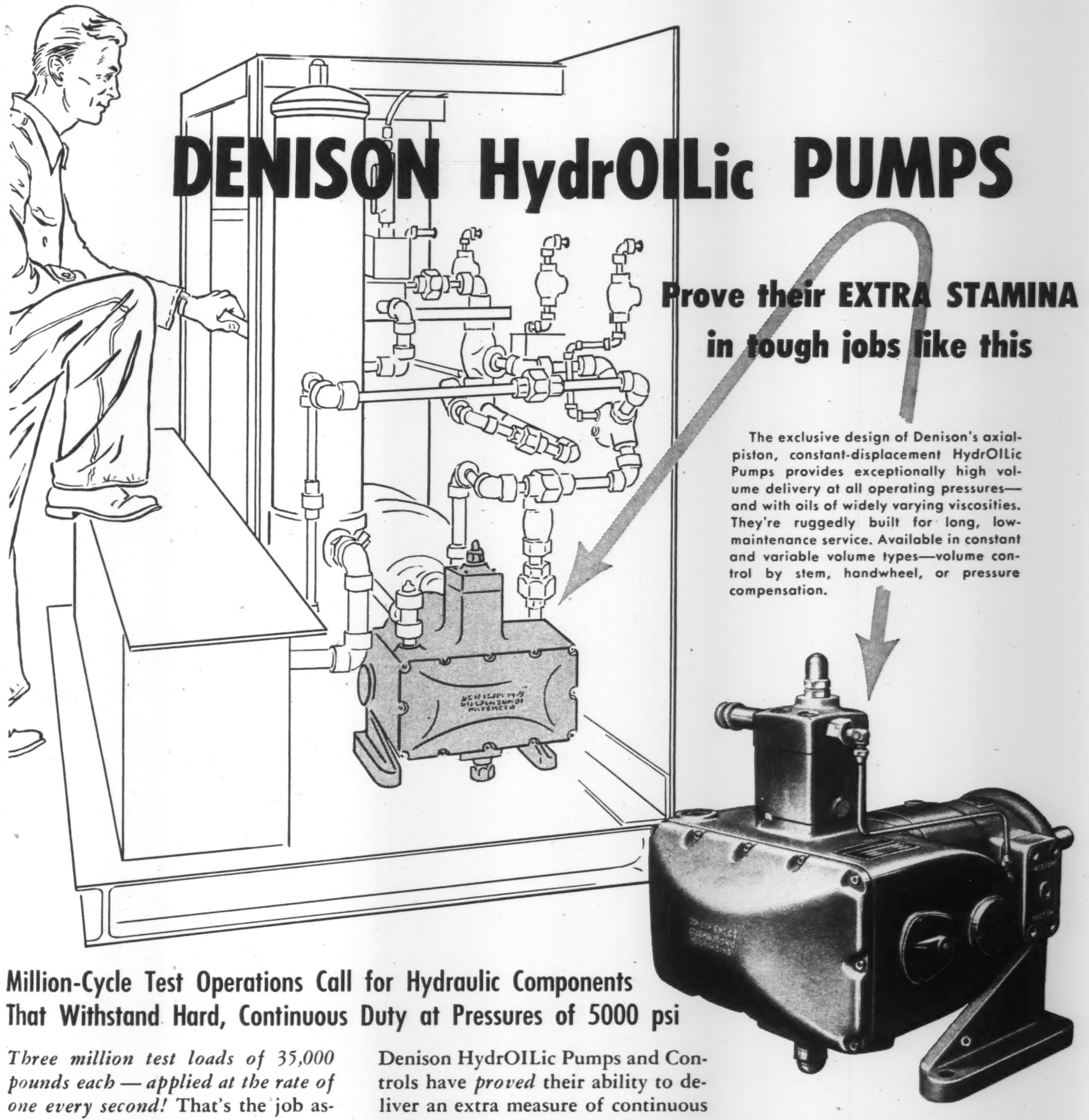
DENISON HydrOILic PUMPS



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Write for further information on the complete line of Denison HydrOILic Equipment.

The DENISON Engineering Co.
1156 Dublin Road, Columbus 16, Ohio

DENISON HydrOILics

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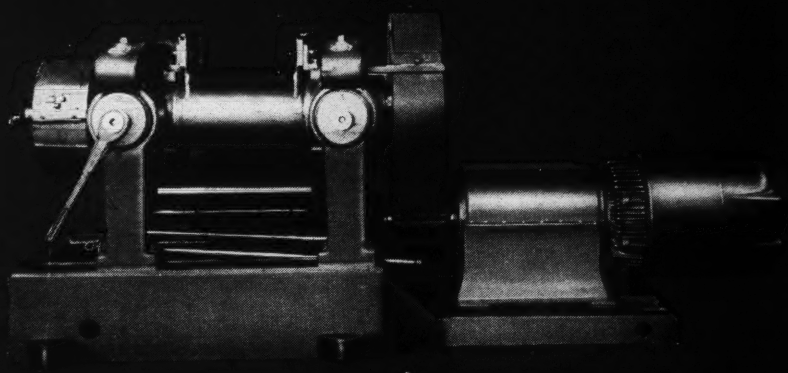

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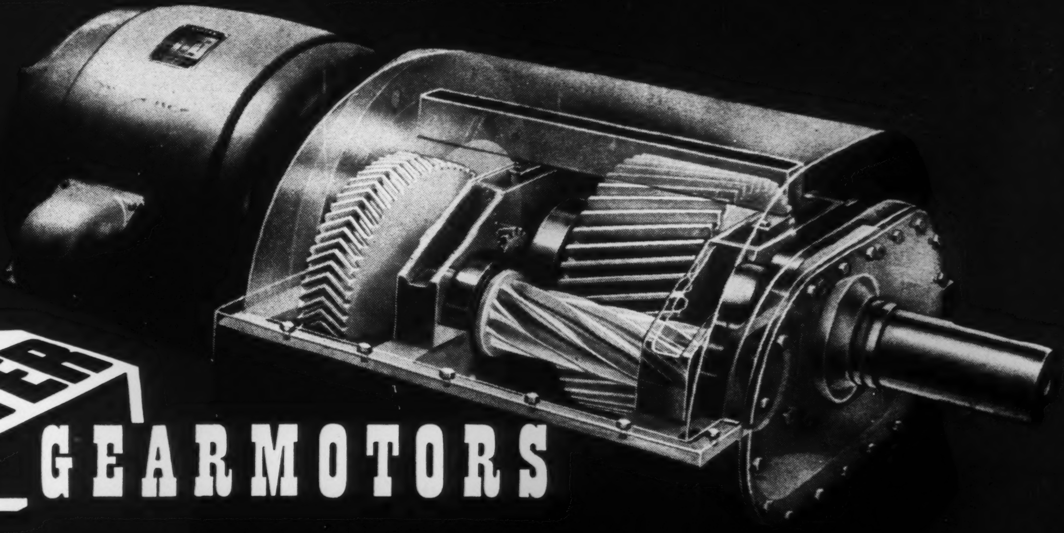

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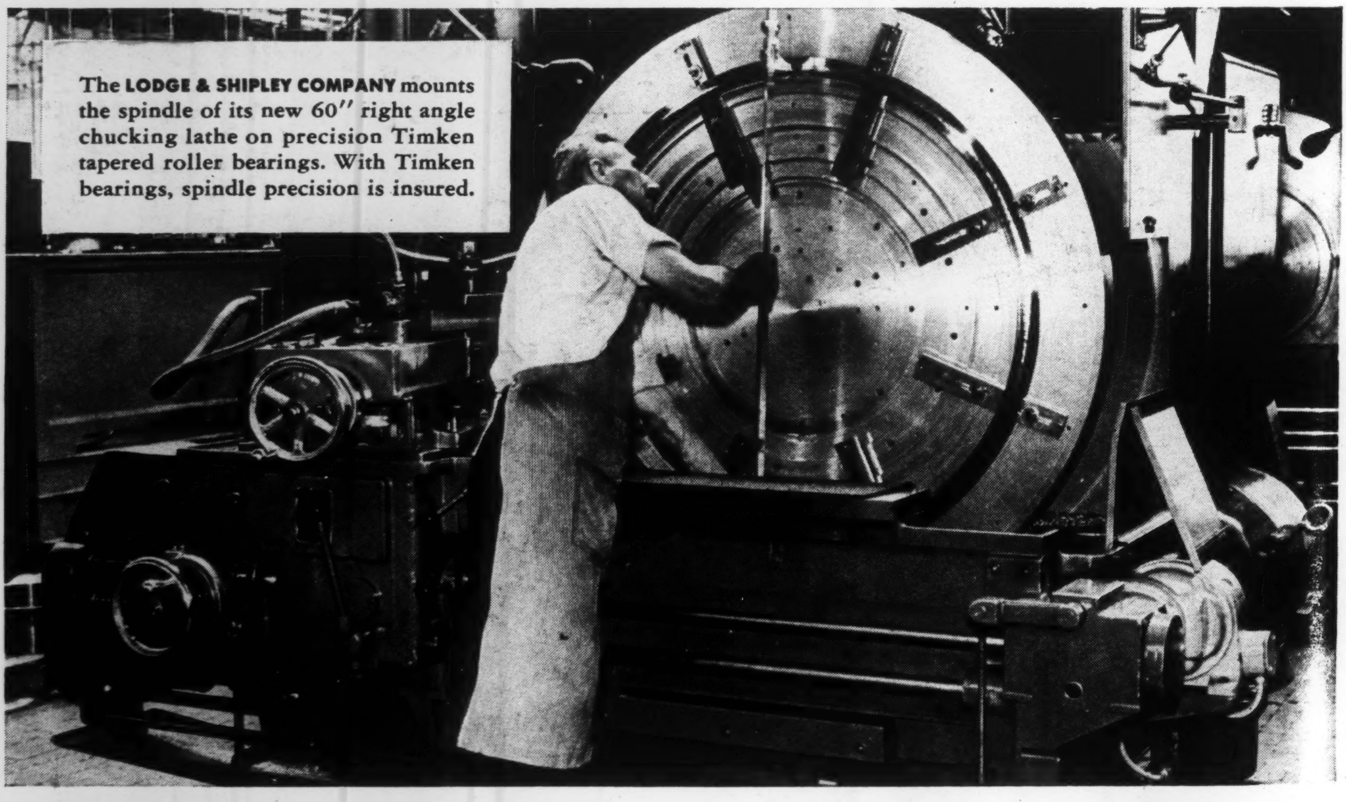

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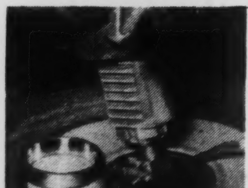

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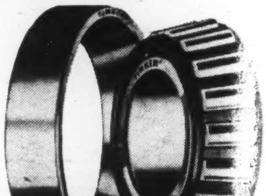

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